



EPA Regional Science Workshop on Stormwater Management



October 20–22, 2009 • Edison, NJ
Final Report

**U.S. Environmental Protection Agency (EPA)
Regional Science Workshop on Stormwater Management
Pines Manor, Edison, NJ
October 20-22, 2009**

Workshop Summary

Tuesday–October 20, 2009

MORNING SESSION

Welcome and Introduction

Logistics

Walt Galloway, EPA Office of Research and Development (ORD), Narragansett, RI

Walt Galloway, the facilitator for the workshop, began by reviewing the agenda, the logistics for the workshop, and some basic “rules of the road.” He noted that all of the PowerPoint presentations would be made available online after the workshop.

Marie O’Shea, Regional Science Liaison for Region 2, introduced the remaining speakers for the morning session.

Welcoming Remarks

Jeff Gratz, Clean Water Regulatory Branch, Division of Environmental Planning and Protection, Region 2, EPA

Jeff Gratz welcomed the participants to Region 2 and noted that the workshop would provide a great opportunity for collaboration with Regions 1 and 3 as well as ORD. He thanked the planning team for its efforts. Recent developments—including the National Research Council (NRC) report to be discussed later in the morning’s program, the new Administration’s serious interest in stormwater management, the issuance of a next-generation action plan for the Chesapeake Bay, and the forthcoming issuance of new stormwater guidelines and permits—make this an exciting time to meet to discuss stormwater. This workshop includes an impressive roster of local and federal experts and timely panel discussions. A major focus of this workshop will be identifying future research needs, with input from all speakers, panelists, and attendees.

Fred Hauchman, Director, Office of Science Policy (OSP), ORD, EPA

Fred Hauchman welcomed the participants on behalf of OSP and noted that a venue such as this is important to enable ORD to understand the work being performed by people in the field, to translate the work into programs, and to go beyond “academic” research to more targeted efforts. He pointed out that workshops like this one are designed to bring people together, not only for the event itself, but for long-term follow-up as well. He thanked the Risk Management Research Laboratory in Edison for its contributions to the workshop.

Regional Science Integration Team (RSIT)

Ronald Landy, Acting Director, Regional Science Program, ORD, EPA

Ronald Landy began his presentation by pointing out that Regional Science Workshops (RSW) are designed to provide opportunities for ORD and other scientists to meet with people from the regions and states to improve their ability to focus their research efforts on regional and state needs. Each RSW

should culminate in some type of future activity. A Regional Science Integration Team (RSIT) is under consideration as a follow-up to this workshop.

The RSIT concept was developed and presented at the 2007 Regional Science Summit between the Deputy Regional Administrators and the senior management of ORD. The concept is based on the success of the large-scale Mid-Atlantic Integrated Assessment (MAIA), but will be implemented on a smaller scale, recognizing current resource limitations. An RSIT would bring together interested regions, program offices, and ORD components to identify the highest priority research needs and develop a multidisciplinary collaborative research plan. The plan would address those needs utilizing the full portfolio of ORD research opportunities, cutting across ORD laboratories and disciplines, and taking advantage of appropriate external research opportunities. The research priorities would be targeted for the appropriate ORD program and collectively form a mosaic of integrated projects, creating the RSIT research strategy.

The Stormwater RSIT will be the first RSIT to be developed. This topic was chosen for the initial effort to create an RSIT because of its high importance as a research priority and because the present workshop provided an opportunity to test the RSIT concept. The goal of the Stormwater RSIT is to develop and implement a multidisciplinary collaborative research plan to address wet weather flow research needs, utilizing all available ORD research opportunities. Primary members will include the EPA regions, the Office of Water (OW), and ORD, with external researchers from states, academic institutions, nonprofit institutions, and the private sector as partners. The research needs identified at this workshop will be the foundation of the Stormwater RSIT.

All participants in the workshop have been asked to complete a research priorities questionnaire to identify: (1) the most important current stormwater issue that needs research funding; (2) the benefit to be derived from research on this issue; and (3) a critical issue that needs to be considered for future research, perhaps 5 years or more from today.

Ron Landy showed the group a needs matrix that could be used as a starting point to link research needs with laboratories and other facilities that could address them. He explained that a special session would be held at the end of the workshop, on Thursday afternoon, for EPA staff only, to discuss the formation of the new RSIT and to take the first steps toward implementing it. The results of the special session will be reported back to workshop attendees.

Collaboration Training

Walt Galloway, EPA ORD, Narragansett, RI

Walt Galloway reported that EPA recently started a program on collaboration, in which both he and Paula Estornell of Region 3 have been trained. The goals of this workshop—to share information on stormwater research issues and to form a stronger network of wet weather management professionals in preparation for the establishment of the Stormwater RSIT—are tasks for which the ideas and tools for successful collaboration can be helpful.

Collaboration is working together with one or more people to define and frame a shared problem, develop options, identify preferred solutions, and plan implementation of a sustainable solution. Good collaboration involves both an attitude and an approach. Components of the attitude that make collaboration successful include: the desire to be cooperative, working to understand others, flexibility and creativity, working as partners, and facilitating each other's efforts to become leaders. The approach involves a deliberate process throughout the full decision life cycle, including the designing, convening, and implementation stages. It includes willingness, openness, civility, humility, and partnering.

Interactions can involve varying degrees of collaboration. EPA interactions with the public range from the least collaborative approach, outreach, through information exchange, recommendations, agreements, and stakeholder action. If a collaborative path is chosen, it is important to commit to it and follow up on it.

Increasingly, any effort to accomplish a goal requires the crossing of boundaries. The MAIA did this on a large scale. RSITs represent a smaller-scale effort to work across the boundaries within EPA and within ORD, and then to partner with other experts and stakeholders outside of EPA, including academia and the states. Keys to successful collaboration in the RSIT include: a clear vision and purpose, people (committed leadership and good representation), information and resources (including funding issues), and communication and dialogue (maintaining regular contact and celebrating success).

Keynote Address: Ecological Impact of Stormwater From Urban Development

Mary Freeman, U.S. Geological Survey (USGS)/Patuxent Wildlife Research Center

Mary Freeman began her presentation by saying that she would be speaking from her viewpoint as a stream ecologist working in ecosystems increasingly affected by urbanization and stormwater. She presented an overview of the major ecological impacts of urban stormwater and the strength of the documentation for these impacts.

Currently, it is known that stormwater runoff alters the physical template of stream ecosystems, consistently increasing the frequency and often the magnitude of high-flow events; sometimes altering base flows; and destabilizing stream channels through erosion, widening, deepening, and/or sedimentation. Small storms consistently cause more frequent high-flow events in more impervious watersheds. The effect of imperviousness on low-flow events is not as well understood; findings have been less consistent, perhaps because many other factors acting in urban streams, such as leaky infrastructure and septic systems, may act as modifying agents. In stream channels, more frequent flows may lead to increased channel instability, but specific effects are unpredictable because they vary with local slope, topography, geology, sediment availability and transport, and other factors.

The effects of hydrology are predictable. In a naturally vegetated watershed, most precipitation is intercepted by vegetation. Precipitation infiltrates, flows down, and comes up to the surface in the form of streams and wetlands. With urban development, the number of small streams decreases, thus speeding runoff and decreasing water storage capacity. Constructed stormwater conveyances do not perform the same functions as natural streams because they do not slow runoff or store much organic matter. Water chemistry alters with urbanization, with increased conductivity, increased contaminant loads, higher nutrient levels, and reduced nutrient retention.

Species losses are characteristic of urbanized streams. For both macroinvertebrates and fishes, the number of species decreases because species that are sensitive to environmental change are lost. A small number of more tolerant taxa become dominant. Studies in both the Blue Ridge Mountains and the Piedmont have shown that with urban growth and an increase in the proportion of impervious surfaces, many species endemic to and adapted to the region were lost, while native but more cosmopolitan species increased, leading to a homogenization of the system. Some of the fish species that are being lost are regionally rare, threatened, or endangered, so there is a strong conservation concern. Some species are very sensitive to impervious area effects; sharp declines in their probability of occurrence can be seen at levels of effective impervious area as low as 2 percent.

In summary, stormwater runoff alters the physical template of stream ecosystems, alters water chemistry, and is associated with species losses; these effects vary depending on other stressors, geomorphology, physiography, previous land uses, the riparian condition, and urban area development patterns. The mechanisms for these alterations are not well understood because observational data are the basis for most current knowledge. Possible mechanisms include disruption of food webs, depression of microbial function, changes in productivity, effects of toxic substances, and thermal alterations, but the roles and relative importance of these mechanisms are not well understood. The impact of nineteenth-century agriculture, which preceded twentieth-century urbanization in many areas, also is not well understood. Current research questions focus on improving predictability, determining what is attainable with reasonable restoration, and developing more effective stormwater management methods.

Discussion

A participant asked whether there had been any research on the impacts of effective impervious cover (IC) on species in the habitat setting. Mary Freeman replied that this is an important issue. Although total IC can be used as a predictor of effects, much better predictions can be obtained by examining how much of the IC is connected.

Rob Traver asked whether the statistics are different for effective versus total IC. Mary Freeman answered that in studies where researchers have reviewed both, effective IC is the better predictor.

Tom Schueler commented that effective IC is the better metric, but is very difficult to measure at the subwatershed scale. Mary Freeman agreed.

Sandy Blick noted that definitions of terminology vary and asked what Mary Freeman meant when she referred to effective IC. Mary Freeman replied that generally, if pavement or rooftop is surrounded by vegetation, she and her colleagues consider it disconnected. Thus, values for effective IC are estimates.

Bill Lucas, who is performing an IC analysis in Prince George's County, Maryland, where geographic information systems (GIS) coverage is very accurate, noted that it has been possible in this setting to obtain highly accurate estimates of connected and disconnected IC.

Urban Stormwater Management in the United States, National Research Council Report Overview

While introducing the next speakers, Marie O'Shea pointed out that several years ago, EPA had asked the National Research Council (NRC) to review the Agency's stormwater program and provide recommendations. Last year, the NRC published a report on this subject, entitled *Urban Stormwater Management in the United States*. The next two speakers were members of the subcommittee that produced this report, and their presentations focused on its recommendations.

Robert Traver, Villanova University

Robert Traver began his presentation by explaining that the task of the NRC subcommittee was to: (1) clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria, (2) consider the value of monitoring, (3) evaluate the relationship between different levels of stormwater pollution prevention plan (SWPPP) implementation and in-stream water quality, (4) make recommendations for how best to stipulate provisions in stormwater permits to ensure that discharges will not cause exceedances of water quality standards, and (5) assess the design of the stormwater permitting program.

The impact of urbanization is well recognized. It is episodic, and the urban impact is much greater than the percentage of the land that is considered urban. Correlative studies have shown that various parameters associated with urbanization of streams co-vary in important but complex and poorly understood ways. The NRC subcommittee agreed that there is a direct relationship between land cover and biological condition and that protection of aquatic life requires an approach that incorporates all stressors. Urban land planning, land use, and source protection also were discussed as part of the problem. To address stormwater in the United States, all of these factors must be addressed, including consideration of the full sequence and distribution of flows. Roads and parking lots are the most significant type of land cover with respect to stormwater.

The NRC subcommittee noted that industrial permitting needs much work. Some states did not know whether or not the correct facilities were being permitted, and often there was no difference in the monitoring requirements for facilities that would have very different types of impacts. Continuous flow-

weighted sampling methods are best. Targeting is needed, with a focus on those sites having the greatest risk associated with their stormwater discharges.

Modeling is helpful, but much remains to be learned. It is difficult to assign specific problems to individual sources because of the uncertainty in current models, gaps in the available data, the scale of the problems, and the presence of multiple stressors. Current understanding of the effects of increases in impervious surface at the watershed level is much greater than current understanding of the effects of individual contributors.

In terms of effluent guidelines, the NRC subcommittee did not consider percent removal to be a useful measure because it does not account for the condition of the influent water.

The NRC subcommittee identified 20 broad categories of stormwater control measures (SCMs). The subcommittee made a point of using the term SCMs in preference to best management practices (BMPs). Enough is known to design SCMs that can reduce the effect of urbanization, but it is not proven that such measures actually will protect streams. The subcommittee recommended eliminating the distinction between non-structural and structural SCMs, instead grouping SCMs by function. The need for maintenance of SCMs is crucial.

The NRC subcommittee concluded that individual SCMs are inadequate; instead, a suite of coordinated measures usually is needed, including those formerly known as non-structural (e.g., product substitution, better site design, downspout disconnection, conservation of natural areas). SCMs that harvest, infiltrate, and evapotranspire stormwater are critical to reducing volume and pollutant loading from small storms. Performance characteristics are starting to be established for some SCMs, but additional research is needed. Research also is needed to determine the effectiveness of suites of SCMs at the watershed scale. Improved guidance for the design and selection of SCMs is needed, and retrofitting presents unique opportunities and challenges that differ from those encountered in new development.

Thomas R. Schueler, Chesapeake Stormwater Network

Tom Schueler summarized the policy recommendations in the NRC report as follows:

- ✧ Flow should be regarded as a pollutant.
- ✧ A direct relationship exists between land cover and biological degradation.
- ✧ The current permitting system is not effective. One of its flaws is a lack of numeric expressions of the Maximum Extent Practicable (MEP). Current permits primarily represent paperwork compliance, with few or no numbers in the permits.
- ✧ Construction and industrial permits should be integrated into municipal separate storm sewer (MS4) permits.
- ✧ Urban stream classification and management are priorities.
- ✧ More stringent industrial monitoring is needed.

Of all the permit systems, industrial stormwater is the greatest failure. The number of inspectors is grossly inadequate. Short-term permitting fixes include incorporating numeric expressions of MEP into permits, municipal permit integration, and subwatershed management. Five approaches to numeric expressions of MEP were recommended by the subcommittee: (1) establishing municipal action levels (linked to the National Stormwater Quality Database), (2) establishing site-based runoff or pollutant limits for new development sites, (3) imposing turbidity limits on construction site discharges, (4) developing spatial requirements for MS4 restoration, and (5) establishing IC-based Total Maximum Daily Loads (TMDLs).

Not all of these approaches are needed in any one setting, but the value of these approaches is that they generate numbers that can be enforced.

The total permit burden is several hundred thousand. There is a need to consolidate permits. Not all sites are the same; some have higher potential impacts than others and need greater attention. More funds for monitoring and research are needed. Enough data are available now, however, to allow tiering of sites on the basis of extent of IC.

The subcommittee members thought that watershed-based stormwater permitting and trading could be implemented in some areas, at least on a pilot basis, as is already being done on the West Coast. This would not be the same as the EPA watershed permitting approach. The scale is for larger watersheds with defined water quality and/or biological impairments, involving areas of approximately 50 to 350 square miles (not entire river basins). The state would work with a lead MS4 permittee, with other smaller MS4s acting as co-permittees. In such a system, the population of permits would be integrated so that wastewater and stormwater would be managed together, as would sites covered by and those outside of MS4 designation authority.

The basic framework for watershed permitting would involve centralized local responsibility and authority for implementation, a minimum goal of preventing future degradation of the watershed, assessing subwatersheds, working together to define clear and specific objectives for management and permitting, performing comprehensive impact source analysis, determining the most effective ways to isolate receiving waters from impact sources, developing or allocating funding sources appropriately to allow for effective implementation, developing a tiered monitoring system to enable direct assessment of progress toward goals, and developing a market system of trading credits as a tool available to municipal co-permittees.

The impact source analysis would be an alternative to the current pollutant-by-pollutant monitoring system, embracing both water quantity and water quality and taking into account the effects of flow. It would include both existing and future development, with evaluation of stormwater hotspots and assessment of contributions from the entire population of permittees. It also would include impact sources that currently are not regulated and would focus on landscape alteration. The NRC subcommittee coined the acronym ARCD for Aquatic Resources Conservation Design, referring to regionally adopted performance standards that apply to new and existing development, as well as redevelopment, and focus on runoff reduction to maintain natural hydrology. The NRC subcommittee discussed a tiered monitoring system, including a progress evaluation tier (before/after in a small watershed), a diagnostic tier (identification of impact sources), compliance monitoring (perhaps the weakest link at the present time), and a research tier (mechanistic monitoring to improve practices and understand impacts).

Tom Schueler ended his presentation by discussing monitoring, noting that with a shift to stormwater pollutant math, there is a need for basic data on BMPs and program performance. There should be a shift toward biological and public health indicators of water quality. The National Stormwater Quality Database is adequate to characterize runoff quality. Sampling should be shifted from consultants to scientists, and compliance monitoring is needed.

Panel Discussion on Stormwater Management Needs

Stephen Silva, Chief, Water Quality Branch, Office of Ecosystem Protection, Region 1, EPA

Jeff Gratz, Region 2, EPA

David B. McGuigan, Associate Director, Office of National Pollutant Discharge Elimination System (NPDES) Permits and Enforcement, Region 3, EPA

Richard Field, Leader, Urban Wet-Weather Flow Research Program, Urban Watershed Management Branch, National Risk Management Research Laboratory (NRMRL), ORD, EPA

Rachel Herbert, Water Permits Division, Office of Wastewater Management, EPA

Robert Traver, Villanova University

Thomas Schueler, Chesapeake Stormwater Network

Marie O'Shea started the panel presentation by asking the panelists to address the major focus and direction of EPA's stormwater program in the coming years.

Steve Silva said that he believes that EPA will move beyond the 1999 stormwater rules and 2003 permitting system to more quantitative measures to stop problems from becoming worse and to prioritize progress on already-impaired streams. He expects to see increased watershed planning and more attention paid to stormwater management for commercial development.

Richard Field discussed EPA's future direction in the area of wet weather flow. Sanitary Sewer Overflow (SSO) rulemaking has yet to be completed, although it has been in process for years. Wastewater treatment augmentation for peak wet weather flow will be an increasing focus at EPA. The Science Advisory Board has recommended that ORD concentrate on emerging contaminants in stormwater and wet weather flow because relatively little has been done in this area. Pathogenicity is a major issue; the appropriate assessment and indicating organisms have not been identified. Total watershed water management is a high priority. More needs to be done with dissolved solids and tiny colloids. Social acceptance and relative incentives are areas on which the Agency will focus. Tailored solutions, as opposed to national criteria, may be the most desirable approach for specific watersheds. EPA also will be focusing on climate change and on the integration of pollution, flood, and erosion control. In addition, the Agency has embarked on integrating green and gray infrastructure for combined sewer overflow (CSO) control; a few cities already are doing this, and more will do so. New urbanization and development are separate items; everything learned from the work mentioned above can be applied to the planning and urbanization process.

Jeff Gratz said that the NRC report was a shot across the bow at EPA. The Agency will be making an effort to implement its recommendations, reviewing flow volume, impervious surfaces, watershed permitting, and both regulatory and non-regulatory options, among other topics. The Chesapeake Bay watershed is a major area of concern, and EPA is trying to use the regulatory tools from the NRC report in implementing its action plan for the Chesapeake Bay. In the regulatory area, EPA will be focusing on minimum performance standards for post-construction runoff. There is a potential to expand MS4s through regulations and to strengthen the new construction effluent guidelines. Regions have been asked to take a closer look at existing tools. More TMDLs with a strong stormwater component can be expected. The BMP approach has not been successful, and a much more aggressive look at MS4 permitting and other regulatory options and tools is needed. The resource and financial burdens of new approaches will be placed largely on municipalities. This makes it much more important for EPA to develop cost-effective tools based on sound science.

Rachel Herbert observed that much of what has already been said is consistent with the views of EPA Headquarters.

David McGuigan expressed the view that the ultimate form of collaboration is strong permits and aggressive enforcement. He believes this is the way to make stormwater programs more effective. One overwhelming problem, in his opinion, is that permits have not been effectively written or enforced. There is no tie between permits and water quality; the current permits are basically just bureaucratic exercises that are unenforceable. To make permits more effective, enforceable metrics related to water quality are needed. There have not been many significant MS4 actions, except for failure to submit permit applications. Small municipalities without the resources to conduct watershed planning will be asked to do so; the process has to be made simpler for these municipalities in terms of establishing clearly definable objectives and providing the tools with which they can achieve their objectives. States need to be encouraged to prioritize; this is not happening now. Construction permitting and MS4 permitting should be integrated so that the two programs complement each other and share the same goals and methods. Pilot projects need to be moved into the mainstream and translated into regulatory requirements rather than discretionary activities.

Rachel Herbert said that EPA Headquarters is taking the NRC report to heart. Headquarters has established a few workgroups, one of which is trying to establish a post-construction performance standard. Much current permitting does not cover rapidly expanding urbanized areas. There may be a need for new regulations, based on data from the 2010 census. Ideally, post-development conditions should mimic pre-development conditions as much as possible. Pilot projects in New Mexico and Minnesota have shown that it is possible to accomplish a great deal in terms of looking at the impacts of specific conditions. EPA Headquarters is trying to follow up on the draft report that was prepared on the Chesapeake Bay. The Agency is extending the deadline for the EPA Construction General Permit so that construction effluent guidelines can be incorporated into this permit to strengthen it. Another Headquarters priority is to improve enforceability and strengthen stormwater permit language. An MS4 permit improvement guide geared primarily toward smaller communities is in development.

Robert Traver mentioned the unit process approach as an enabler. Enough is known to begin reviewing evapotranspiration, infiltration, percolation, absorption, biological conditions, and the hydrology of green roofs, pervious concrete, and rain gardens. There is a need to target designs and understand how these processes work in the landscape. The performance of green infrastructure has been undervalued, in his opinion. Climate change is an important issue, as is scientific maintenance. Right now, efforts are being made to design stormwater management systems that last 50 years, which is discouraging green infrastructure. There is a need to determine how long installations really work and to make stormwater management practices more effective and science-based.

Tom Schueler said that the NRC subcommittee welcomed EPA's response to its report. When stronger permits with numerical requirements were developed for the Chesapeake Bay, it triggered extensive change. The existing system, with some significant reform, can be effective. There is a need for a professional network at all levels, from the designers to the researchers, to the regulators and plan reviewers, to work together. Stormwater is complex and confusing; a group with diverse expertise can create better solutions than any individual could alone, allowing the development of rules and permits that can be implemented in the real world.

Marie O'Shea asked the panelists to give their views on the most significant obstacles to successful stormwater programs and on the highest priority research needs in the area of stormwater management.

Robert Traver commented that change is a key point. It is important not to use old paradigms in dealing with the stormwater problem.

Steve Silva stated that a real problem exists with convincing people that it is possible to do something about the impacts of stormwater, with regard to both new and existing development. People need the tools to choose the right set of design measures and BMPs for a particular setting. People need to be confident that the stormwater measures they take or require others to take will work. There are still many regulators who are unwilling to step outside of the narrowest interpretation of the 1999 stormwater rules. Promising developments include new analytical tools, GIS tools, and modeling tools that facilitate the examination of small watersheds and the development of cost-effective methods for addressing stormwater in those watersheds. For example, in Region 1, a pilot program in three communities on the Charles River has used a BMP Decision Support System (BMPDSS) model to plan stormwater management cost effectively. There are signs that the understanding and technological capability are there, but more effort is needed in terms of people's attitudes and on the regulatory side.

Jeff Gratz noted that programs must be cost effective because they impose an additional resource burden on communities. Within the Agency, there will be major program additions at a time when resources are decreasing. These are barriers that will require major efforts to overcome. Another important issue involves determining whether the water quality criteria currently in place are appropriate.

Richard Field said that the obstacles to success include high cost; social acceptance, especially by private property owners; lack of life cycle cost analysis; lack of long-term operations and maintenance (O&M) requirements; lack of consideration of long-term groundwater impacts; and failure to apply engineering

knowledge to the design of controls. There is a need to integrate programs and disciplines—including science, engineering, and activities of municipalities and the Federal Government.

David McGuigan stated that there is a pressing need to determine the link between water quality and permit requirements. There is a need to develop a meaningful metric. EPA needs to be able to make clear policy choices about what to regulate; some small jurisdictions cannot do this themselves.

While traveling around the country, Rachel Herbert has noticed that successful programs have had strong management support. If managers at all levels can be convinced that stormwater management is a valuable use of resources, much can be accomplished. It is important to coordinate modeling efforts to avoid repeating similar projects and to allow pooling of funding. The multiple benefits of green infrastructure need to be recognized; green roofs and similar measures have other types of benefits, such as energy savings, as well as being useful in stormwater management. Maintenance of BMPs or control measures is critical; there is a need to allocate appropriate resources to maintain these controls or they could become sources of pollution later.

Rachel Herbert said that she had asked stormwater coordinators in the regions to identify key research needs and that they had emphasized the following:

- ✧ Studying secondary benefits of green infrastructure.
- ✧ The economic costs and benefits of green infrastructure.
- ✧ Pollution prevention.
- ✧ The toxicity of polyacrylamides and how this relates to turbidity requirements.
- ✧ Better understanding of stormwater management in arid systems, including the toxic effects of sediments in these environments.

Tom Schueler indicated that cost is the number one research need. There are more data on effectiveness than cost. The number two research need is bacteria; there are virtually no data on the effects of bacteria. The third research need is resident attitudes and behaviors; it is time to monitor humans as well as stormwater. Fourth is source area sampling, not just outfall sampling. Much can be learned by monitoring roofs, lawns, parking lots, and similar locations. Only a few studies have collected data from source areas.

Marie O'Shea opened up the panel discussion to comments and questions from the audience.

Kevin Magerr commented that refitting of existing infrastructure is an important research priority. There is a need to determine how to accomplish this cost effectively.

Robert Traver responded that the principles of retrofits are the same as for new installations, but for retrofits, there is a greater need for creativity and imagination on the part of the designer. It is important to remember that a small improvement during a retrofit can have tremendous benefits. Richard Field mentioned that historically, CSO control consisted of using existing infrastructure to its best advantage. The same applies to SSO control. This has been done reasonably well.

Sandy Blick asked the panel about paying for the implementation of stormwater controls. Where will the money come from?

Richard Field responded that money is an obstacle. Rachel Herbert said that she did not know whether specific funding existed. Stormwater grants were available in the past but are not available now. Tom Schueler commented that stormwater financing at the local level is a crucial issue. Steve Silva said that for new development, financing stormwater controls is the responsibility of the developer. For existing development, it is important to take a look at the effects of small storms; even small incremental

improvements are valuable. Evaluating water quality impacts also can be helpful. There will be a need for stormwater utility districts to implement stormwater controls on a long-term basis. Making use of economic recovery grants also can be valuable. Richard Field commented that major governmental economic analyses would pay dividends; for example, the question of whether it pays to install green infrastructure needs to be answered.

Zeyuan Qiu suggested that there has been too much research emphasis on differences rather than commonalities in different watersheds. This makes the research effort too complex. Is it possible to leverage all of the research efforts to obtain a more complete understanding? In the policy arena, to date the focus has been on stormwater related to urban development. Will the watershed still be emphasized? How can EPA's efforts be integrated with those of other agencies?

Robert Traver responded that there is a tendency to forget how much is known already. For example, the importance of small storms is understood. On the policy side, there is a lack of consideration for maintenance. Therefore, designers are only concerned about what will get past a review rather than the long-term consequences for the property owner. Tom Schueler said that watershed complexity should not be overemphasized, but the existence of distinct physiographic regions must be recognized. The watershed-based permitting approach developed by the NRC panel recognizes that the system cannot be effective unless both the watershed and the non-urban land uses within it are taken into account.

Robert Roseen asked whether, as the new permit cycle comes out, any consideration has been given to requiring as a permit element the creation of a stormwater utility. Municipalities in some areas may not have the authority to regulate stormwater or create funding mechanisms for stormwater control, which can serve as a barrier to implementation. He also commented that the attitudes of engineers may be a barrier to implementation in some situations; often, engineers are resistant to change.

Tom Schueler noted that in the 1990s stormwater rule there was a provision for demonstrating adequate financing within the permit, but this has not been enforced. The engineering community may indeed be a barrier; often, engineers think that low-impact development (LID) is impossible. Robert Traver observed that policies also may limit engineers' choices. Standards need to be set in such a way that engineers will design appropriate technologies to meet them. David McGuigan noted that EPA sometimes overestimates costs. As controls become required, the network of engineers and planners tends to make them affordable. Richard Field commented that it has been rewarding to see the changes that have taken place since the 1970s.

AFTERNOON SESSION: WATERSHED ASSESSMENT AND ECOLOGICAL RESPONSE

Moderators: Charles App, Region 3, EPA; Ralph Abele, Region 1, EPA

Introduction to Session and Panel I

Charles App introduced the afternoon session, noting that the focus would be on watershed assessment, and that the session had been divided into three topic areas, with an opportunity for members of the audience to ask questions at the end of each portion of the session.

Panel I: Stream Ecology Monitoring and Assessment Approaches

Addressing Urbanization in CADDIS (The Causal Analysis/Diagnosis Decision Information System)

Kate Schofield, ORD, EPA

Kate Schofield began her presentation by explaining that the Causal Analysis/Diagnosis Decision Information System (CADDIS) is an online application that helps users conduct causal assessments of stream biological impairment. She showed the audience the CADDIS home page, explaining that the revised version to be released in 2010 would look quite different.

One of her early experiences with the CADDIS project involved a case study in Long Creek, Maine, an impaired watershed located just outside the city of Portland. Multiple stressors were present in the watershed, and it was difficult to determine their relative importance. The CADDIS modules contain information on eight common stressors—including four of the five potential stressors identified in Long Creek—with guidance on when the stressor should be considered, common sources and responses, and other topics. Stressors, however, do not occur in isolation. The CADDIS site currently is being updated so that multiple stressors can be considered simultaneously, and four new stressors are being added. The updated version of CADDIS also will include an interactive conceptual diagram (ICD) for urbanization, with the ability to query for relevant literature. The ICD was originally developed as a brainstorming tool and only contains supporting references for linkages. In the future, it is hoped that additional data can be added, including data that weaken linkages as well as data that support them. Geospatial data, quantitative data, and management options also may be added.

The new ICD application also allows users to modify existing diagrams or create new diagrams and link their own references to them; thus, it provides a useful tool as users conduct site-specific causal assessments. As the public editing capabilities of CADDIS are further developed, its developers see this type of tool having great potential as a collaborative platform—basically, a wiki-type diagram that users can populate with their own information and data or those borrowed from other users' diagrams.

Kate Schofield closed her presentation by pointing out that the prototype source module and ICD for CADDIS are in draft form; the developers would welcome input on the types of information or capabilities that potential users would find helpful.

Shepherd Creek: A Case Study of Watershed-Scale Stormwater Retrofits and Ecological Monitoring in Cincinnati, Ohio

Allison Roy, Kutztown University

Allison Roy, a former postdoctoral fellow at EPA, presented findings based on a collaborative case study in which she had participated while at the Agency.

Sources of stormwater originate throughout a watershed, and mitigation therefore should occur at the watershed scale. Watershed-scale stormwater restoration, however, faces multiple challenges. Barriers include the lack of an appropriate legislative framework, jurisdictional issues, lack of sufficient funds and resources, lack of appropriate market incentives, the absence of full-scale engineering guidelines, and the presence of social barriers, including lack of vision and resistance to change. The challenges are multidisciplinary, and the solutions also should be multidisciplinary.

In the Shepherd Creek watershed, where the case study was conducted, the total impervious area is only 13 percent (with about half connected), but effects of stormwater are evident. GIS data and a ground survey indicated that the impervious areas were mostly on private property. Therefore, the decision was made to mitigate with rain gardens and rain barrels, which would be offered to property owners in four of the six subwatersheds through a system of market-based incentives (the other two subwatersheds served as controls). Results to date indicate that the market-based mechanism provided appropriate incentives;

extensive monitoring through 2011 will indicate whether quantifiable hydrologic, ecological, and water quality improvements occurred.

The market-based incentive was structured as a “reverse” economic auction, in which homeowners were offered rain gardens and rain barrels for free and were asked to bid on how much the project had to pay them for the privilege of installing these BMPs. Participants were told that funds were limited, so they were bidding against each other, which provided a motivation to keep bids low; many bids were zero. Bids were awarded based on cost and environmental benefits. The bidding process was conducted twice, in 2007 and 2008, and 31 percent of eligible households bid over 2 years.

The threshold for detectable ecological improvement is approximately 8 to 12 percent impervious area. Given the BMP acceptance rates in this study, it is projected that some of the subwatersheds will reach this zone but none will go below it. Therefore, biological changes may not be seen, but effects on water quality and hydrology may be detected. If other pollutants (e.g., leaky septic tanks, road salt) or sources of runoff (e.g., roads) are overwhelming the system, however, improvements in stream ecosystems may not occur. The long-term impact of this project depends on homeowner acceptance and willingness to take responsibility for maintenance; the BMPs will not be maintained by the Agency after the project ends in 2011.

Allison Roy noted that studies of this type are difficult. They require substantial resources, and involve dealing with both nature and people. Unanticipated events may complicate the interpretation of results. For example, during this project, a road in the watershed was resurfaced, vegetation adjacent to a road was removed, and sewer replacement was planned. Despite such complications, such projects are valuable because they are the only way to know whether specific mitigation measures actually improve stream health.

Stressor Identification-Fish Community Response to Flow Alteration and Imperviousness in Massachusetts Streams

David Armstrong, USGS Massachusetts/Rhode Island Science Center

David Armstrong reported on a statewide project just beginning in Massachusetts to study fish community response to water withdrawal, motivated by the need for state agencies to understand how much water can be withdrawn from stream systems without altering aquatic communities. Several recent Massachusetts-Rhode Island projects have been related to the issue of evaluating water management alternatives and their effects on streamflow and habitat availability, but more needs to be known about the effects of both physical basin characteristics and human alteration on fish communities. In particular, it would be useful to be able to distinguish effects of water withdrawal from those of IC.

In a pilot study that simulated flow alterations in three watershed models, declines in endemic fish species were observed. Above a certain level of IC, however, the relevant species may be completely lost, and therefore they cannot be used as indicators. The number of fish species in New England streams often is small—as few as two to seven—which also may hamper analysis. Another difficulty is that fish communities respond to many variables. One goal of the current study is to determine the relative importance of these different factors.

A new tool, the USGS sustainable-yield estimator (SYE), can be used to simulate altered and unaltered flows for ungaged sites; the simulated flows include the effects of groundwater and surface water withdrawals and returns but not land use effects.

A total of 1,500 fish sampling sites have been identified through screening of sites from a larger database; a variety of metrics, including species richness, indicator species metrics, trophic composition metrics (i.e., types of habitat use), and fish abundance and condition, will be assessed at these sites. Exploratory data analysis indicates that species show distinct differences in response to drainage area and that responses to IC may be in part due to a correlation between drainage area and IC. Tolerant species (such

as American eel) could easily be distinguished from less tolerant ones (such as brook trout). Next steps include multivariate analysis of the relation of a variety of physical basin and human alteration factors to fish community metrics to determine which factors have the greatest impact, cluster analysis to determine which types of fish species co-occur, and analysis of the correlations among environmental and human alteration variables.

Region 1 Regional Applied Research Effort (RARE) Project: Use of EMAP and State Data To Refine an Index of Urban Intensity for New England, and an Application of the Index To Improve Measures of Aquatic Community Impairment

Naomi Detenbeck, ORD, EPA

Naomi Detenbeck discussed work currently being conducted to develop regional stress/response relationships between urbanization and biological metrics and potential applications of that approach for assessing stormwater BMP effectiveness. The objectives are to refine an index of watershed development for New England, develop watershed development/biological or water quality condition relationships as a tool to distinguish point source from non-point source effects, and test the utility of the watershed development index tool. The basic concept is to develop curves for region responses versus urban intensity. In instances where responses, such as indices of water quality or the presence of pollution-tolerant versus intolerant species, are outside of the predicted range, it then would be important to determine what factors are responsible.

Data from 731 watersheds, derived from three datasets, are being analyzed. Sites were first stratified by ecological unit. The background flow regime also is important because it can influence sensitivity to stressors. Relevant New England basin characteristics related to peak or low flow include watershed area; main channel length and slope; lake and pond area; percent wetland area; percent impervious area; percent coarse glacial till, outwash, and stratified drift; rainfall depth; percent of forested area; mean elevation; seasonal precipitation averages; and annual mean temperature. An analysis using a combination of two statistical techniques (Bayesian classification and regression tree analysis) indicated that drainage area was the best predictor for different peak flows.

Preliminary conclusions indicate that models that incorporate the variable “ecounit” explain more variation in biologic measures than those that do not include this variable and that the reference condition and the sensitivity to urbanization can vary with both geographic unit and flow regime. With greater imperviousness, there is loss of some sensitive taxa and a shift in trophic composition, as well as a loss of some habitats.

Data analyses currently in progress will finalize conclusions about macroinvertebrate responses, add a metric for coefficient of community loss, and examine the potential for improving predictability of models by studying local- and buffer-scale metrics as well as watershed-scale effects. Based on the results of this research, it should be possible to propose better ways to tease out flow effects versus urbanization effects. Future research may focus on evaluating the benefits of implementing different stormwater BMPs, extending the findings to fish communities, and examining the response to different habitat metrics. The methods used are readily applicable to other EPA regions and to national datasets.

Discussion

Dale Monty asked about the relative difficulty of recruiting participants in the Shepherd Creek study. Allison Roy responded that the number of participants was relatively high given that only a mail survey was used for recruitment; there was no large-scale educational campaign, just a demonstration and brochures. Word of mouth accounted for much of the recruitment in the second year; thus, greater participation could be expected if the effort had continued for a longer period of time.

Rob Traver asked what will happen if no effects are detected in the Shepherd Creek project despite all the buildup. Allison Roy responded that another phase of research is planned; it will include stormwater runoff from roads, which was not considered in the initial study.

Jeff Moeller asked Allison Roy whether her study had any data on the cost of installing rain gardens. Allison Roy said that TetraTech performed all of the installations and that the cost, with maintenance three times per year, was more than \$2,000 for a 150-square-foot rain garden.

Gerald Bright asked whether reintroduction might be an appropriate part of stream restoration. Allison Roy replied that fish reintroduction has been considered in some locations but not macroinvertebrate reintroduction.

Sandy Blick asked whether, in the Shepherd Creek study, there is any long-term guarantee or restriction to prevent homeowners from removing the installed rain gardens. Allison Roy responded that people own the properties and have the right to do what they want; legally, the participants in the study could not be required to keep the rain gardens. In fact, the agreement between the researchers and the participants states that if the participant desires, the researchers will remove the rain garden after 3 years.

Lambro Bourodimos asked who coded the literature included in CADDIS. Kate Schofield replied that she had performed the initial literature searches; the papers were coded by multiple readers, after which the different codes assigned by the readers were reconciled. It is hoped that in the future anyone will be able to enter references into the database and upload them so that all users can see them. A group in Australia has developed a similar database, and an effort is under way to combine the two.

Panel II: Prioritization of Sub-Watersheds (Tributary Streams) for Stormwater Remediation

Ralph Abele introduced the second set of speakers for the afternoon session.

Detecting Regional Biological Responses to Watershed Imperviousness: Resolving Taxon-Specific and Community Thresholds Using Threshold Indicator Taxa Analysis (TITAN)

Matt Baker, University of Maryland-Baltimore County

Matt Baker began his presentation by noting that the literature suggests the existence of ecological thresholds—that is, points at which a small change in a driver leads to a large change in response. The concept of ecological thresholds is controversial.

Many approaches to the investigation of synchronous turnover of species have been developed; some are overly idealistic or assume linearity. In general, many involve retrofitting univariate techniques to a multivariate system.

Matt Baker described a new approach called TITAN, which combines Classification and Regression Tree (CART) analysis with indicator species analysis. TITAN is an integrative measure that is not biased by group size. It distinguishes the strength and direction of a response, that is, the increase or decrease in a species, while trying to maintain the maximum indicator score. The magnitude of this score depends on abundance and occurrence frequencies. The strengths of TITAN are that it quantifies taxon-specific analyses and allows a picture of an entire ecosystem to be built. It also distinguishes unimodal from bimodal distributions of taxa, and it is nonparametric.

When TITAN and more traditional methods were tested on simulated data involving 36 species and 120 samples across a gradient, in which the data included a threshold change point, TITAN detected the threshold but the other methods did not. TITAN was able to capture the threshold while building evidence for a community-level response from individual taxa.

When TITAN was applied to real-world data from small and large streams, it detected sharp declines in taxa richness at less than 1 percent IC in both types of environments—a finding that differs sharply from the results of other methods, which typically have indicated that effects occur only at substantially higher percentages of IC. Because the sample size used was large and many covariates were accounted for, there is good reason to think that the TITAN findings are real. In addition, responses for fish and amphibians were similar to those for macroinvertebrates. The threshold for the decline in taxa richness coincides with a threshold in specific conductance, possibly induced by road de-icing salts or other toxic agents. The findings from the TITAN analysis imply that biodiversity declines in streams may occur at much lower levels of urbanization than previously considered.

Prioritizing Workload Using a Model To Predict Biological Condition

Chris Bellucci, Connecticut Department of Environmental Protection

Chris Bellucci focused his presentation on: (1) IC as a research tool, (2) Macroinvertebrate Multi-Metric Index (MMI) model development, and (3) using this information to prioritize workload.

Data from the State of Connecticut indicate that no sites in streams meet aquatic life goals if the IC upstream of the site exceeds 12 percent. This provides a basis for setting TMDL goals. Streams and their potential management strategies can be classified as “best” (IC less than 7 percent; require preservation), “streams with hope” (IC between 7 and 12 percent; require active management); and “urban streams” (IC 12 percent or greater; require mitigation). The latter two categories of streams are found primarily in the most urbanized portions of the state (along the Connecticut River and in the far southwestern corner of the state).

MMI modeling has expanded IC work by including other factors that potentially affect the biological condition of a stream. A methodology has been established to predict the expected biological condition at an unmonitored site utilizing geospatial analysis of readily available drainage basin data. The dataset was weighed by the proportion of surface area in each major Connecticut basin, and sites in each basin were randomly selected for study. Of 43 variables examined, those that stood out as most significant were drainage area, IC, and average diversion amount. Multiple linear regression indicated that IC was the most important of these three variables, at least in the coarse data currently available.

The MMI modeling data can be used to optimize resources and as guidance for decision making. For example, those streams that slip from the middle category to the most impaired category could be prioritized for future monitoring and remediation. The MMI findings also can be used to inform anti-degradation policy and to enable a statewide assessment of stream quality.

Recovery Potential Screening To Assist Restoration Priority Setting

Doug Norton, OW, EPA

Doug Norton explained that recovery potential screening is a method to help impaired waters restoration planners recognize “best bets” for restoration. It is a flexible, indicator-based, GIS-driven comparative process that uses landscape and monitoring metrics from commonly available datasets. Recovery potential is the likelihood of an impaired water to reattain Water Quality Standards or other valued attributes, given: (1) its ecological capacity, (2) its exposure to stressors, and (3) the socioeconomic context affecting efforts to improve its condition.

A restoration and recovery literature database has been developed as a tool for regions and states. It includes approximately 1,600 key-worded citations, some annotated, relevant to restoration success factors. It will be made available as an open, user-modifiable database in MS Access that will be downloadable from Watershed Central.

Another tool is recovery potential indicators, developed from literature and practice, which have plausible relevance to the likelihood of recovery and are measurable from readily available data. Approximately 60

metrics in three classes (ecological, stressor, and social) are in use and others are in development; indicator reference sheets provide summaries of information on these indicators. Indicator summary scores can be calculated, and screening plots allow three summary scores to be visualized simultaneously. When a single summary score is preferred, the equation (ecological summary score + social summary score)/stressor summary score can be used.

A pilot study in Illinois examined 104 indicators and found that this number of indicators was too large to be workable. A recovery screening project in the Mid-Atlantic states, focused narrowly on native trout recovery factors, had greater success. A project currently in progress in Region 4 is using indicators to target and prioritize watershed restoration and protection efforts, focusing on major impairments—nitrogen, phosphorus, pathogens, and sediment. A project in Maryland involves recovery potential screening at two scales—one very localized and the other involving larger areas, thus allowing for screening subwatersheds within one priority watershed.

In summary, priority setting for restoration is inevitable and will continue to affect the nation's restoration efforts. The screening methods described here detect differences among impaired watersheds, allowing for better informed decision making. A clearly focused screening objective and appropriately selected metrics and data are crucial. Finally, there is a need to build up the scientific basis for better prediction of restorability.

Discussion

Murray Lantner asked whether, given the potential for significant biological effects with even small amounts of development, there is any hope for saving streams. Matt Baker responded that many analyses at broad spatial scales do not take into account population dynamics that could help with recovery. Simply developing a general awareness that biodiversity is being lost is helpful. Doug Norton said that he had heard of dramatic data from Maryland on effects at very low thresholds of IC and was shocked by them. To find hope, there is a need to look for a sign that some things can be accomplished. Chris Bellucci said that there is a need to educate people about the impacts of land use. Matt Baker commented that unless efforts are made, there will be no way to know whether a response can be achieved.

Zeyuan Qiu acknowledged that it is necessary to prioritize because of limited resources and asked whether any ethical or equity issues need to be considered. Doug Norton responded that priority setting is inevitable; it is not possible to do everything. In choosing indicators, it is possible to do so sensitively and fairly or to do so very badly, especially with regard to social indicators. If a state believes that a history of environmental justice concerns should be taken into account, this can be incorporated into the ranking system. Flexible scoring systems for setting priorities are needed. It is difficult to do this well, but if there is an established method for doing it, at least transparency will be achieved.

Sandra Fancieullo asked Doug Norton for more information about the Web site that he had discussed and about the social context metric that is used. Doug Norton responded that the plan for the Web site is to have a site that will describe recovery potential screening from the standpoint of helping people to go through the steps. It is anticipated that the Web site will be ready within 2 months, but this estimate may be optimistic. Social metrics include a large family of metrics. Social scientists have helped in their development. Socioeconomic characteristics are not the only factors that are considered. Other factors, such as relative certainty of the impairments, relative costs, and the involvement of various government agencies, also are considered. Many of the social metrics are difficult concepts to measure.

Panel III: Stream Ecology and Engaging the Public

Ralph Abele introduced the speakers for the last portion of the afternoon session.

Vermont River Management: Restoring Stream Equilibrium Conditions Through Floodplain and River Corridor Protection

Mike Kline, Vermont Agency of Natural Resources

Mike Kline explained that stormwater-impaired streams in Vermont are impacted by sediment contributions from the channel bed and banks as the result of channel incision and widening processes. Stream power, which is a function of water depth, slope, and flow resistance, has been changed by these processes. In addition to efforts to address stormwater issues in Vermont, efforts are being made to understand and deal with the changes in components of stream power, with the ultimate goal of bringing the hydraulic geometry and longitudinal profile of channels back into equilibrium.

Many urban streams in Vermont that are now on the 303(d) list (i.e., waters that do not meet water quality standards) have been subjected to modifications for more than 200 years. Deforestation, snagging and ditching, dams, diversions, dredging, and berming all have contributed to stream alterations. For decades, efforts were made to straighten streams to make them more suitable for moving logs to mills. By the mid-nineteenth century, 70 percent of the state was cleared, and many rivers had been straightened. In many Vermont valleys, anywhere from 0.5 to 2 meters of organic rich alluvium has accreted in the valley floors as a result of deforestation. Many streams today still lack access to their historic floodplains because of this accretion. Although the extent of deforestation in Vermont has been reduced from the historic maximum of 80 percent to 20 percent, past deforestation still affects stream quality. Depositional streams have been converted to transport streams because channelization has altered their hydrologic and sedimentation characteristics; this in turn has influenced cover, feeding, refuge, and reproduction habitats of various species. The current effects of urbanization and IC must be viewed in the context of previous stream alterations. Ephemeroptera, Plecoptera, and Trichoptera (EPT) species richness is low in incised or widening streams but increases as stability improves.

Bringing channels back into equilibrium requires an understanding of sediment regimes and equilibrium at the watershed scale. Key parts of a river system may need to be protected so that sediment can accumulate appropriately and floodplains can redevelop. Constraints, such as bridge abutments and undersized culverts, may need to be removed. River corridor protection and restoration still are possible in many urban areas, but in others, structures have been constructed too close to rivers to allow the channels to return to their natural locations. When presenting the importance of stream stability and LID to the public, it is helpful to emphasize public safety issues.

Beyond Technical Analysis—Overcoming Internal and External Obstacles to Maine's Urban Stream TMDLs

Melissa Evers, Maine Department of Environmental Protection (DEP)

Melissa Evers explained that most urban streams in Maine are biologically impaired. Stressor analysis has indicated that IC is a reasonable surrogate for impairment.

The principal challenge to stream restoration lies not in identifying the problem but in motivating people to solve it. Even within the DEP, reactions include skepticism regarding the effectiveness and enforceability of non-point source TMDLs, beliefs that the TMDL approach is not the correct tool for watershed management, and controversy surrounding the issue of whether TMDL reductions may derail watershed planning or influence higher-level politics.

Outside of DEP, reactions to IC TMDLs tend to follow the classic stages of grief:

- ✧ *Denial.* People try to avoid having to take action or change their current practices. They express the view that “This cannot be true for us.” They assume that past building permits and BMPs were sufficient to keep streams healthy and are shocked to learn that streams are not meeting water quality standards.
- ✧ *Anger.* In a frustrated outpouring, people question the basis for the determination that streams have not met water quality goals, assume that the goals are unattainable, and express negative views about the flaws of the TMDL method. These reactions can be considered good news because they mean that people’s attention has been drawn to the situation.
- ✧ *Bargaining.* People want to know more and become receptive to educational efforts. They may ask whether the stream can be downgraded so that improvement would not be necessary, but discussions begin to focus on possible solutions.
- ✧ *Acceptance.* At this stage, people are willing to find a way forward. They accept that the stream needs to be restored and are willing to work on developing and implementing a watershed management plan. Local buy-in is crucial at this stage.

In dealing with external stakeholders, DEP has learned that the legal and technical requirements of the Clean Water Act concerning TMDLs are not easy to understand. The connections to biological endpoints are difficult to convey, and instream water quality can be an abstract concept. It can be hard to explain why millions of dollars must be spent because of the types of “bugs” in the stream. In addition, the fact that DEP cannot ensure success is a problem. DEP can only offer a reasonable judgment concerning restoration potential; it cannot provide guarantees.

Future directions for the Maine DEP include retrofitting specific watershed management plans and considering implementation through stormwater utility districts, which would improve funding. Residual designation authority also has become an important issue.

Discussion

A participant asked whether there have been reductions in impervious area in Maine and what approaches have been successful. Melissa Evers replied that implementation in Maine has been spotty, and there is no large list of successes. The DEP is still trying to get people to acknowledge the problem and deal with it. There is a 10-year time frame for implementation. Things are moving slowly and the costs are high, so implementation is not easy.

Hale Thurston commented that a way to avoid layers and property rights issues is to talk about effective imperviousness as well as real imperviousness. Melissa Evers replied that disconnected versus connected IC has been a point of contention when TMDLs are renewed. Most older developments already have some stormwater controls, so the owners want credit for them. There are varying degrees of control within the watershed, and it is important to acknowledge this in the watershed management plan. For developing TMDL targets, however, Maine is using basic GIS IC layers. The DEP does not have the ability to distinguish effective imperviousness from total imperviousness.

Todd Richards asked Mike Kline whether he has been able to obtain buy-in from the public safety people for his argument that public safety is an important consideration in stream restoration. Mike Kline replied that he manages both programs. About 10 years ago in Vermont, the stream restorationists joined with river engineers and the floodplain management program to form an overall rivers program. Thus, people from all of these areas of expertise speak with one voice in Vermont, advocating managing toward stream equilibrium as a way to simultaneously achieve water quality, habitat, and public safety goals.

Doug Norton commented that he was pleased to see the discussion of applying stream geomorphology in Mike Kline's talk. He asked how the use of geomorphology could be "sold" given the squabbles among geomorphologists about classification. Mike Kline responded that he has adopted every one of the geomorphologists' various classification systems so that no faction can object. He agreed that the disagreements among geomorphologists detract from the ability to bring a large-scale, process-based approach to stream restoration.

Steve Silva commented that IC TMDLs have focused people on the cause of the problem and have forced development of watershed plans. Maine has made it clear that efforts are being made to reduce the effect of IC rather than IC itself. He asked whether there has been any shift in DEP from IC TMDLs to a watershed plan. Melissa Evers responded that there is movement in that direction, but only a small group of people is involved in the program.

Session Wrap Up

Charles App commented that the session had been awesome and he complimented all of the speakers, noting that they had set a very high bar for the other sessions. He summarized the highlights as follows:

- ✧ CADDIS is a very useful tool that likely will receive more hits on its Web site after this workshop. The CADDIS upgrade should be available in spring 2010.
- ✧ The Shepherd's Creek study has generated much interest, particularly in its reverse auction methodology, and he is looking forward to seeing the final results of the study. One important take-home message from this study is that there is a need for longer-term pilot projects.
- ✧ Several speakers made the point that loss of sensitive, native species is an important consequence of increasing IC.
- ✧ There is a need to reconcile the results of Matt Baker's work with other IC work.
- ✧ Social indicators are important, and more attention needs to be paid to them.
- ✧ A recovery potential screening tool will soon be available.
- ✧ He believes that the answer to the question "Is there hope?" is yes, especially if people in a watershed care about protecting this resource.
- ✧ Mike Kline's presentation was particularly interesting because of its focus on 200 or more years of stream modification. Other evidence suggests that people have been modifying streams for even longer, going back to the time of the Anasazi Indians.
- ✧ It was news to him that the streams in Vermont were in such poor condition, and it is very worthwhile that Vermont is attempting to restore floodplains.
- ✧ Melissa Evers' presentation applying the steps of the grief process to water quality impairment was very interesting, and the point that she made about biological endpoints being difficult to "sell" is important. Some endpoints may be easier to sell than others, though; for example, endpoints involving reproducing trout have been readily accepted.

Ralph Abele added that approaches to stormwater control need to be multidisciplinary. He also commented on Matt Baker's work, noting that biology should be brought into the discussion. There is a need to accept the results of this study and its analysis, even if some people are uncomfortable with them.

Wednesday, October 21, 2009

INNOVATIVE STORMWATER CONTROLS

Moderator: Kevin Magerr, Region 3, EPA

Morning Session

Introduction

Kevin Magerr introduced the session by emphasizing that research is a key to moving stormwater management forward. He reviewed the session goals, which are to:

- ✧ Showcase current research in stormwater controls;
- ✧ Respond to regional concerns, including BMP maintenance, assessment, longevity, and retrofitting;
- ✧ Present information on barriers to implementing innovative stormwater management controls; and
- ✧ Discuss future stormwater management research needs.

Innovative Stormwater Controls

Robert Traver, Villanova University

Robert Traver began his presentation by pointing out that some stormwater controls once thought of as innovative, such as green roofs and rain gardens, are now regarded as mainstream, at least by stormwater professionals. The true innovation today involves controls that are designed to be sustainable. He described some controls implemented by the Villanova Urban Stormwater Partnership in the Philadelphia area, where typically there are only 12 precipitation events of greater than 1 inch per year. One is a bioinfiltration traffic island, which is a retrofit that has about a 10:1 BMP to impervious area ratio. It was constructed in 2001 with a simple design that achieves an infiltration rate of ½ to 1 inch per hour, thus decreasing runoff on an annual basis by about 70 percent. The performance of sites such as this can be modeled using traditional hydrologic models, but variability in infiltration rate—which has been shown to be linked largely to temperature—complicates the modeling process.

Concerns have been expressed that stormwater controls such as this will inevitably fail. Statistics from Maryland, New Jersey, and Washington State, however, indicate that even if BMPs are designed, located, constructed, and maintained poorly, they work approximately 50 percent of the time. At Villanova, infiltration pits that had been constructed in the 1890s were found to still be functional when tested recently, even though they had been disconnected in the 1970s.

Performance data were collected for a porous concrete site and an infiltration trench and compared with those for the bioinfiltration traffic island, and the results showed that each BMP had its own characteristic recession limb from storm to storm, but the only BMP showing any sign of failure was the infiltration trench. The most sustainable of the three sites is the bioinfiltration traffic island.

Robert Traver said he often suggests to designers in Pennsylvania that they design a rain garden as the stormwater control for the first inch of rainfall. Other controls, such as a rock bed, are needed only for a few larger events per year and will last longer as backup controls than they would if they were relied upon exclusively.

Comparisons of the Villanova installation with some at North Carolina State University have indicated that the installations in North Carolina, which has sandier soil, are more effective in larger storms,

whereas the Villanova site, because it is larger, is more effective in smaller storms. Comparisons of this type are helpful in determining design parameters for stormwater controls.

Current studies are examining evapotranspiration on green roofs and in a hanging rain garden, determining the relationship between temperature and recession rate, and assessing toxicity. The effects of the BMPs on orthophosphate, nitrogen, and copper are being investigated. Orthophosphate has been decreasing over time, which might be related to the buildup of metals in the soil. Groundwater monitoring is showing increased conductivity directly under the installations and also at sites upstream; the latter findings suggest contamination from other sources, such as dumped snow containing de-icing agents.

A participant asked what variables were responsible for denitrification and orthophosphate removal. Robert Traver responded that the answer to this question would be known in about a year; a study on this topic is in progress.

Maintenance and Monitoring of BMPs

Tom O'Connor, ORD, EPA

Tom O'Connor discussed monitoring and maintenance at two BMP sites in the Staten Island Bluebelt in the Richmond Creek Watershed. BMP RC-5 is an open water wetland marsh with a forebay and stilling basin; RC-4 is a similar installation with a slightly larger drainage area. For RC-5, the short-term objective of monitoring was to demonstrate statistically valid results for solids removal. In the longer term, the BMP was monitored for a variety of water quality constituents (nitrogen, phosphorus, chemical oxygen demand [COD], indicator organisms) and monitored during and between events with electronic probes (for pH, temperature, and ammonia).

Prior to maintenance, effluent concentrations of COD were high, exceeding influent concentrations; this is indicative of breakthrough. After maintenance, in which four truckloads of sediment and leaf litter were removed from the site, statistically significant improvements in effluent concentrations of COD and phosphorus were observed. Variability in the COD and phosphorus content of effluent from one storm event to another decreased after maintenance, presumably because there was not as much material to discharge.

Leaf decomposition was the principal factor responsible for the high COD in the effluent before maintenance. Leaves can break down in a matter of days, contributing to COD and releasing ammonia. The leaves come from the 0.5 acre site itself and from its 23-acre watershed.

At site RC-4, sediments and tissues from macroinvertebrates were sampled for metal content before and after maintenance. Copper, lead, and zinc all increased after maintenance, which was not the expected result. Maintenance may have affected heavy metal sediment concentrations, at least temporarily. The disturbance involved in maintenance may impact BMP performance for metals removal and increase metal bioavailability.

In summary, this investigation of the effects of maintenance had mixed results. Solids were being removed effectively, and maintenance did not improve this. Maintenance led to reductions in COD and phosphorus in effluent. Leaves appear to be a major contributor to the COD and phosphorus load. The New York City Department of Environmental Protection has modified its cleaning schedule based on the findings of these tests, and now includes tributary catchbasin cleaning in its maintenance procedure. There is a need for predictive relationships for maintenance schedules tailored to all contaminants of concern, not just sediment. Further investigation of the effects of maintenance on metals is needed.

Discussion

Luz Garcia asked why the data shown indicated differences in the patterns seen for lead and copper. (There was more lead in the wetland than in the BMP, whereas copper showed the opposite pattern.) Tom

O'Connor responded that this difference likely reflects the fact that lead is no longer used, but copper is used.

Systematic Stormwater Retrofits

Robert Roseen, University of New Hampshire (UNH)

Robert Roseen began his presentation by explaining that the University of New Hampshire (UNH) Stormwater Center operates a testing facility and conducts outreach. More than 20 systems, one-half of them manufactured devices, have been tested at the site.

Stormwater retrofits provide both the greatest opportunities and greatest challenges in stormwater control. In developed areas, retrofitting is the only way to reverse water quality impairments. In most instances, retrofitting only occurs in response to regulatory drivers, such as NPDES Phase II, TMDLs, and Residual Designation Authority (RDA), which is being used in Region 1 (the first region to do so). RDA addresses sources of pollution not covered under existing programs; this includes pollution from pre-existing development.

At existing sites, space already may have been allocated to stormwater maintenance infrastructure, providing an obvious starting point for retrofits. Many constraints may be in place, however, such as limited space, legacy issues (brownfields, contaminated soils), intensive usage of space above and below ground at urban sites, and fear of wet basements and infiltration. Common retrofits include vegetated buffers, bioretention, tree filters, gravel wetlands, porous pavements, subsurface chambers, subsurface filters, and hydroseparators. Controls that lead to reductions in both volume and total solids are needed. There is some question as to whether any removal of nitrogen occurs; the same vegetative systems that remove nitrogen also release it.

Robert Roseen displayed examples of retrofits implemented in New Hampshire, including a gravel wetland at a park-and-ride at an Interstate highway exit; porous asphalt in a little-used overflow parking lot at another park-and-ride; a section of road paved with porous asphalt; and a commercial development on a brownfields site with multiple controls including subsurface infiltration, some use of porous asphalt, and a gravel wetland on the sides of the site to allow for nitrogen removal.

Common concerns encountered with retrofits include the need for and cost of maintenance, issues related to snow storage, concerns about the durability of porous pavements, and doubts about the effectiveness of newer techniques. It is not possible to provide municipalities with the same level of assurance about the reliability of newer techniques as with older ones, and this is a problem that must be acknowledged and addressed head-on. Older techniques, however, will not meet current water quality requirements.

Overcoming Social Barriers to Stormwater Implementation

Thomas R. Schueler, Chesapeake Stormwater Network

Tom Schueler began by asking several members of the audience to volunteer to play the roles of EPA, a state agency, a researcher, a designer, an advocate, and a municipality in a brief piece of “watershed theater” later in his presentation. He said that the topic he was asked to address is a very serious one but that he preferred not to approach it in a serious way. He then likened overcoming social barriers to stormwater implementation to the experience of persuading his teenage daughters to wash the dishes.

Implementing stormwater controls, especially in a large and highly impacted area such as the Chesapeake Bay watershed, requires profound changes in human behavior, including: shifts in where and how land is developed, changes in how sites are laid out, a shift to a new LID paradigm, increased stormwater treatment, greater ownership and management of old IC, and enhanced stewardship on urban land. These changes require a variety of actions involving large numbers of people, including codes, new technology, regulations, permits, retrofitting, and outreach and education. At the present time, the needed changes are only beginning to be adopted, and many people have not yet been drawn into the new paradigms.

Tom Schueler described four models for changing behavior: (1) the rational actor model, (2) the motivated actor model, (3) the regulated actor model, and (4) the collaborative theater model.

The rational actor model, which has been the basic approach to stormwater control for the past 2 decades, assumes that when provided with the correct information, rational people will change their behavior accordingly. The parallel here is explaining to your teenage daughter why the dishes need to be washed and asking her to do so. This approach tends to have limited success. Most people are busy and distracted by competing interests, some people are highly resistant to change, no clear signal is given that change is really needed, and the approach is passive and does not generate enthusiasm.

A second approach, the motivated actor model, provides technical assistance and incentives to motivate people to change their behavior—for example, teaching one’s teenage daughter how to wash the dishes and offering her a small increase in her allowance if she washes them. In the case of stormwater, this approach, which has been used only to a limited extent, involves stormwater grants, stormwater credits, practice subsidies, expedited plan review, and free training. This approach has not had substantial success in the stormwater arena because the financial incentives have been small and usually one-time, the motivations of the target population are not well understood, stormwater costs are usually only a small factor in total decision making, and no strong commitment has been made to this approach.

The regulated actor model involves prescribing exactly what the actor has to do and then providing consistent feedback until it is done properly—as in, for example, standing over a teenage daughter until she finishes washing the dishes properly and taking away a privilege if she does not comply. In the case of stormwater, this approach involves numeric performance standards, technology requirements, TMDLs, more stringent permits, inspection and enforcement, and program accountability and compliance. This approach seldom has been implemented in the stormwater arena, although officials often threaten to do it. Regulation has not been pushed because it is complex, difficult, and poorly supported by some stakeholders. It is easy to write regulations, exhausting to adopt them, and intimidating to enforce them.

The fourth approach—the collaborative theater model—was illustrated by asking the volunteers to simultaneously and repeatedly state the top priorities and concerns of their particular agency or group while spinning in circles. The point was to illustrate that many stakeholders are involved in stormwater issues, and all their viewpoints need to be heard for a successful solution to be developed. A first attempt at hearing everyone’s viewpoint, however, may not be successful, as illustrated by the skit. The collaborative theater model involves assembling all stakeholders as a network, sharing information, agreeing on minimum performance standards with flexibility on how to achieve them, respecting everyone’s role in the process, and recognizing that “rehearsals” may involve many failures that will need to be ironed out before “opening night.” This approach, unlike the others, may be successful because it creates a culture of implementation, replaces isolation with collaboration, assigns roles for all professionals, integrates across all levels of government, recognizes the value of science and economics, and establishes accountability for everyone.

Overcoming social barriers requires monitoring humans, not stormwater. It requires determining the current attitudes and behaviors of residents and stormwater practitioners, as well as transparent reporting of inspection and enforcement data. There is a need to identify: (1) how behaviors change in response to different outreach or regulation strategies, (2) the forms of training that are most cost-effective in fostering change, and (3) the best models for permit enforcement and accountability.

Staten Island Bluebelt: A Model Green Infrastructure Program

Dana Gumb, New York City Department of Environmental Protection

Dana Gumb presented a case study from Staten Island, New York, where a regional stormwater program has been implemented. Here, there is a successful brand, the “Bluebelt,” which has become so well known and respected that other New York City boroughs want it, though primarily for the open space and

community beautification it provides, rather than for stormwater management. Staten Island, unlike most of the rest of New York City, still has some suburban areas, open areas, and wetlands. It is the last large part of New York City without sewers, and it has failing septic systems and street flooding. The drainage system planned for the southern part of Staten Island in the 1960s assumed full sewerage and elimination of the wetlands; it was never implemented. There has been a need for new drainage plans that provide the necessary infrastructure and preserve the wetlands. The Bluebelt vision is to use green, not gray, infrastructure and create a drainage system that is economical, responsive to flooding and draining problems, environmentally sensitive, acceptable to regulatory agencies, beneficial to the community in a variety of ways, buildable, and practical to maintain. The overall strategies are to: develop the stormwater management system using existing wetlands, collect street runoff in storm sewers, and use BMPs at the sewer-wetland interface. A detailed planning process and cost-benefit studies to secure budgetary approval have been undertaken. Drainage was planned on a watershed basis using mathematical models.

Some of the lessons that were learned from this project about creating stormwater wetlands include the following:

- ✧ It is necessary to protect plants from herbivores.
- ✧ Dry weather water depth should be limited to 18 inches.
- ✧ It is preferable to plant live plugs in the spring, rather than planting dormant rhizomes in the fall.
- ✧ Stormwater flow into the wetland should be restricted for one growing season.
- ✧ Plants should be selected on the basis of water quality.
- ✧ Gentle slopes promote the growth of vegetation.
- ✧ Flexibility in outlet structure should be provided so that the water level can be manipulated.

The speaker showed photos of several of the Bluebelt BMPs, including a pocket wetland, an extended detention basin, a retrofit of an existing detention basin, and an outlet stilling basin, at various stages in their development and maintenance. One important feature of the program has been the development of “maintenance cards” that specify the short-, moderate-, and long-term maintenance necessary for each BMP.

Problems encountered with the BMPs include invasion with exotic vines and damage from herbivores such as muskrats. It has been necessary to install fences in some locations to exclude animals. Aspects of the Bluebelt program that have worked well include good relations with the Parks Department, vertical integration of functions, community involvement, and making environmental review integral to the planning process. Challenges include stream restoration efforts, public education, erosion control, and the ongoing battle with invasive exotic plants. Next stages for the Bluebelt program include developing a system of BMPs for fragmites—sections of wetlands cut off from each other by roadways. Planning for the fragmites must take into account both stormwater issues and the risk of fire in the marshes.

Discussion

Murray Lantner asked: (1) about the extent of problems with clogging and maintenance of porous pavements; and (2) when cleaning out retention ponds, whether there are issues with wildlife, such as amphibians and turtles, using the ponds. With regard to the first question, Robert Roseen responded that it is necessary to be realistic about the durability of porous asphalt. It is less durable than standard asphalt and will fail sooner. All systems fail at some point, however, and in the Northeast, even standard pavement only lasts 8 to 12 years, so periodic replacement is to be expected. Maintenance will add to pavement longevity, but more needs to be learned about how best to maintain porous pavement. Clogging is less of a problem than durability. A porous asphalt surface will work effectively even if some areas

clog. Catchbasins can be included in the installation as a backup in case the pavement clogs excessively or is mistakenly sealed. Robert Traver said that the risk factors for clogging need to be examined. He has seen a porous asphalt site built 35 to 40 years ago that is approximately one-half clogged but still works adequately because the remaining area is porous.

Dana Gumb said that wildlife, especially snapping turtles, is seen in the Bluebelt installations. Some of the ponds have been very successful in attracting wildlife. With the potential heavy metal problems, however, it is uncertain whether the sites will be viable long-term wildlife habitats. Tom O'Connor pointed out that function is the main purpose of stormwater installations; it is not possible to give a yes or no answer to the question of whether they also will serve as wildlife habitat.

Ron Landy asked Dana Gumb whether he had looked at broader ecosystem opportunities. Is there an opportunity for an ecological corridor? Dana Gumb responded that continuity is needed for floodwater conveyance as well and that this fits in with the need for continuity in wildlife habitat, especially in terms of connecting one park to another. Some wetlands will be lost as a result of the Bluebelt project and others will be created. Thus, there is a need for relatively large-scale planning at the watershed level.

Laura Nicholson asked whether there are any innovative stormwater designs that deal with recharge over cased aquifers—like those found in New Jersey. Thomas Schueler responded that the Chesapeake Stormwater Network has developed a 30-page guidance document for this situation. He noted that traditional ponds often fail in this situation.

Zeyuan Qiu asked Dana Gumb about the relationship between his group and local municipal agencies. He also asked the panel members for their thoughts on how to prioritize BMPs from a watershed perspective. Dana Gumb replied that his organization *is* the municipal agency. Robert Traver responded that getting volume where you can is a high priority. Thomas Schueler stated that it is important to set performance criteria that are stringent but do not constrain the designer, except for discontinuing the use of methods that do not work. Robert Roseen commented that when updating stormwater manuals, people often add new tools but do not remove those that do not work well. It is as important to discontinue the use of ineffective systems as to promote the use of effective ones. Land conservation and cost and site constraints are among the many factors that affect prioritization.

Richard Field described a situation in Texas in which a porous parking lot clogged quickly because of erosion from nearby construction. He pointed out that it is necessary to take the surrounding topography into account when writing the installation specifications for porous pavement. Robert Traver noted that sod around the edge of a porous parking lot can serve as a safety buffer. Robert Roseen stated that the biggest cause of failure is construction and installation. If there is no installation oversight, problems are inevitable. Too high a percentage of porous pavements fail because of construction- and installation-related problems. Robert Traver noted that even if BMPs are built, designed, and maintained poorly, they still work approximately one-half of the time. He also recommended a move toward inspection of the finished product, rather than just inspection of the design.

Emilie Stander commented that an important barrier to getting people to move away from covering their property with turf is property values. Thomas Schueler responded that people's perception of landscaping is intensely personal and that preferences change. There are no data on preferences for turf versus attractive bioretention installations; large trees are more important in terms of property values. He asked whether it might be possible to deal with people's preferences for turf by making lawns spongier or by having a bioretention area with a turf cover. With regard to the total nitrogen issue raised earlier, he said that nitrogen is a difficult pollutant to manage; if you eliminate it in one place, it tends to occur in another, sometimes in a different chemical form. There is a need to go back to a traditional limnological focus on soluble nutrients.

Dale Manty asked about the use of macroscale vegetation—trees and large shrubs—as part of a bioretention system and about how to factor in the sea level rise in low-lying areas. Robert Traver

responded that the depression storage of a tree is of value, but a tree is not of great value during a storm. Dana Gumb said that sea level rise has been one of the arguments for acquisition of land, including fragmites, for stormwater management in Staten Island; it takes people out of harm's way. If the number of people living in low-lying areas can be limited, flooding is less of a problem. The flexible Bluebelt system is better than a hard sewer system with regard to flooding. Tom O'Connor said that the effect of trees in an urban environment may be different than their effect in a forest and that the differences are not well understood. Robert Roseen mentioned that the use of innovative stormwater management controls that add storage to the landscape can help with resiliency to climate change. The landscape has more storage with diffused stormwater controls, and this helps with stressed infrastructure.

Kevin Magerr commented that it is important to study the effects of existing infrastructure on water quality. Efforts are being made in his region to encourage transportation departments to review controls that may go beyond the right of way. There may be existing infrastructure in the area on which they could capitalize. Robert Roseen said that he had not seen this done for retrofits, but there is tremendous opportunity because there are ponds everywhere. Putting gravel in them could create a useful BMP. There are many simple opportunities to improve stormwater controls. Kevin Magerr mentioned that when old systems are adjacent to new installations, it can create a greater opportunity for stormwater control.

Sandy Blick asked about: (1) the debate regarding the use of filter fabric, (2) the relationship of inflow drainage area to porous pavement surface, and (3) the advantages and disadvantages of the use of artificial turf. Thomas Schueler answered that artificial turf should be treated as impervious. Tom O'Connor recommended Amy Roe as a source of information on filter fabric. Robert Roseen said that he does not like to use fabrics unless necessary because clogging can occur. Pea gravel, which is more three-dimensional, can serve the same function as a geotextile with fewer problems.

Ed Frankel asked whether there have been any studies on the use of brine in de-icing porous pavement. He also asked whether de-icing materials would create a groundwater problem later. Tom O'Connor replied that high conductivity in wells indicates that chloride infiltration is a problem. This problem, however, is not unique to porous pavements. In fact, the use of porous pavement can be beneficial because porous pavements require about 75 percent less de-icing material than standard pavements do, mostly because black ice does not form on porous pavement. This more than offsets the lack of accumulation of brine on porous pavement surfaces. Data are lacking on the effects of pre-brining on porous pavements. Thomas Schueler said that there is no stormwater practice that he is aware of that is capable of removing soluble chloride. Therefore, the issue is where the chloride will have an impact—the roadside? In a pond? In nearby vegetation? There are very disturbing data from the Mid-Atlantic region about progressive increases in chloride concentrations in surface waters well into the summer season as the chloride moves through the system. This points to a product substitution issue. Robert Traver noted that there has been an exponential increase in the use of chloride on roads since the 1950s. A member of the audience noted that EPA studies on de-icing have shown multiple impacts, including vehicle corrosion and damage to bridges and reinforced concrete, as well as chloride pollution. Dana Gumb noted that chloride concentrations one-half that of seawater have been observed in Staten Island BMPs. Several panelists observed that the current use of salt on roadways is excessive. Robert Roseen said that about one-half of all salt is used in parking lots, and use in this setting could decrease with the increased use of porous pavement.

Art McGarity asked how land is acquired for the Bluebelt project. Dana Gumb responded that some is acquired by eminent domain, but they are trying to negotiate sales as much as possible. It is difficult to establish the worth of wetlands, which is a reason to avoid condemnation. Some easements have been used, but there is an enforcement problem. In most instances, the stormwater utility needs to have control over the property.

Kunal Patel asked where the line should be drawn for hydraulic capacity. There is a need for a realistic indication of the size of a system. Thomas Schueler said that it is important to understand that large events occur. In a large storm, certain elements will fail. Such situations, however, are not entirely

negative because they draw attention to the need for good stormwater controls. Robert Traver noted that major and minor collection systems can be designed to work together.

Afternoon Session

Moderator: Maureen Krudner, Region 2, EPA

NPDES Stormwater Permitting

Maureen Krudner introduced the presenters for the afternoon session, which focused on the implementation of stormwater permits.

Stormwater Permit Implementation

NPDES Stormwater Permits and TMDL Implementation: A State's Perspective

Pete LaFlamme, Vermont Department of Environmental Conservation

Pete LaFlamme focused his presentation on: (1) innovative new concepts in TMDLs, (2) watershed permitting to implement TMDLs, and (3) Vermont's NPDES permitting experiences.

Vermont has served as the initial laboratory for many developments in the stormwater field. The state's stormwater program is robust, but stormwater management is a 50:50 mix of science and law. The state has 17 listed "urban-impaired" streams, whose watersheds account for ½ of 1 percent of the total state land area. Water quality impairments are measured through analysis of aquatic biota populations, and effects of stormwater runoff are implicated in water quality and quantity issues.

Direct use of sediment in TMDLs can be problematic. Hydrology is more predictable and inclusive than sediment measurements. Target setting can be performed through the attainment watershed approach, which attempts to match conditions in similar streams that currently meet water quality standards.

Implementation issues considered by Vermont's Stormwater Advisory Group (SWAG) include:

- ✧ Recognition of the complexity of implementation, including cost and the difficulty of retrofitting;
- ✧ The need for an emphasis on fairness;
- ✧ The critical need for monitoring of streamflow and BMPs;
- ✧ The possible need for phasing;
- ✧ The critical importance of stakeholder involvement;
- ✧ The possible need to develop stormwater utilities; and
- ✧ The use of a BMP tool and adaptive management.

The outcome of the SWAG process was the development of a general consensus on the overall implementation framework. The general approach involved issuance of state law-based watershed permits as necessary. RDA can be used to regulate stormwater discharges. Under RDA, the state may designate discharges as requiring an NPDES permit under specified circumstances.

The Conservation Law Foundation (CLF) filed a petition asking Vermont's Agency of Natural Resources (ANR) to determine that NPDES permits were required for all existing discharges to five stormwater-impaired streams because they contribute to water quality violations. ANR denied the petition. CLF then appealed to the Vermont Water Resources Board, which sided with CLF. The Board's decision was based on state law cases, which stated that any discharge of a measurable and detectable amount of sediment

contributes to a water quality violation. In response to this decision, Vermont will use a combination of MS4 and RDA permits to implement TMDLs in the five watersheds affected by the decision.

Vermont's experience indicates that altered hydrology has an important impact on stream geomorphology. Endogenous sediment production may be dwarfing wash-off loadings. In addition, to cope with scientific uncertainty, both legally and programmatically, changes to research and regulations pertaining to stormwater implementation and permitting are needed at the national level. Litigation is not a good forum for the development of innovative science and permitting techniques.

Implementation of an IC TMDL

Chris Bellucci, Connecticut Department of Environmental Protection

Chris Bellucci presented a progress report on the implementation of an IC-based TMDL in Connecticut. IC is used as a surrogate for the complex array of pollutants transported by stormwater runoff. The goal is not to reduce the percent IC in the watershed *per se*, but rather to reduce the impact of IC through stormwater management to levels equivalent to less than 12 percent IC.

The first watershed where a TMDL was applied was Eagleville Brook, a 2.5-square-mile watershed with very poor biology that is managed by the University of Connecticut and the town of Mansfield. The implementation plan developed for Eagleville Brook will serve as a template for other IC TMDLs in Connecticut. A roadmap for implementation has been developed, field work has been completed, and the identification and selection of projects to be supported through grants is ongoing. Some quick fixes were identified, including arranging with the university to install pervious pavement in parking lots that were scheduled for repaving. Practical problems were encountered in the transport of pervious asphalt, which leaked extensively out of the trucks that transported it. Other activities involved the development of a green roof at one campus site and rain gardens at others. Construction for a fire suppression project provided an opportunity to install stormwater controls at a campus apartment complex.

Issues for future research include the following: (1) developing information on how much credit is received in response to implementation of a particular BMP, (2) making sure that the costs of restoration are understood, and (3) giving more attention to healthy watersheds in an effort to keep them healthy.

Discussion

Robert Roseen commented that there are ways to control for leakage of liquid porous asphalt. It was likely that outdated procedures had been used at the University of Connecticut site. He also asked how IC and IC reductions are defined. Chris Bellucci responded that determining the definition has been a large part of the discussion with the engineers on the Eagleville Brook project. Questions include what the target really means and what percent reduction means. He hopes that by the time of the final report on the project in spring 2010, better definitions will have been developed. The question is a difficult one to answer.

Dale Manty asked Chris Bellucci for his views on the possibility of integrating fire suppression with stormwater management improvements. Chris Bellucci replied that the experience in the Eagleville Brook project did not involve integrating fire suppression with stormwater management; instead, it was more a matter of taking advantage of the fact that digging was taking place anyway. Equipment was available because of the fire suppression project, and this made it easier to install stormwater controls.

Andy Dinsmore said that he currently is working on a stormwater TMDL team in another state and that RDAs were on his team's mind as well. He had been told, as Pete LaFlamme also had mentioned, that commercial areas draining directly to stream networks are not considered part of MS4. Is it correct that the responsibility goes directly back to the main municipal MS4, and how do municipalities respond to it? Pete LaFlamme responded that municipalities have reacted poorly. His group's goal was to give the municipalities as much responsibility as possible because municipalities provide the only logistically

practical way of implementing TMDLs. Therefore, efforts have been made to define MS4s as broadly as possible. Only in cases where the IC was directly connected to the receiving water was the RDA brought in.

Charles App agreed with Chris Bellucci's statement that there is a need to work on maintaining already healthy watersheds. Region 3 has a pilot healthy waters initiative, which could be expanded into a broader national initiative. Progress, however, has been slow. Those who think that maintaining healthy waters is important should make their views known to OW.

Model Utilization in Stormwater Management Plans

Improving SCMs Using Design Storm (DS) Criteria Verified by Long-Term Analysis From Continuous Simulation (CS) in Storm Water Management Module (SWMM)

Bill Lucas, Integrated Land Management, Inc.

Bill Lucas compared DS versus CS modeling, noting that DS models are inappropriate for SCMs because DS events designed for flooding represent nested maxima for multiple event durations; the chances of this occurring are virtually nil. Nevertheless, DS models are overwhelmingly used by designers and reviewers throughout the United States and typically are required during litigation. CS models are the true test of a system. They provide flow-duration-frequency curves that can be used to evaluate metrics such as stream erosion impacts or the frequency of CSOs. CS modeling is needed for optimization of designs.

Bioretention has a very substantial capability not only to treat runoff but also to retard and delay flows. In bioretention/infiltration/extended detention systems, as used in urban environments, much is occurring in the vertical dimension. It is necessary to model these systems both effectively and rigorously. The DS and CS approaches have both been used in the modeling of bioretention systems. The overall conclusions of such modeling are that 1-inch passive storage handles a 1.5-inch sample event with low infiltration rates, which is equivalent to providing a 90 percent reduction in CSOs. DS modeling has indicated that by using realistic design storms and discrete routing, it is possible to project the behavior of a planter/trench system over a variety of conditions. The system can be set up so that bypass begins just beyond a 1.5-inch event. This results in cost efficiencies in better soils because less than 1 inch of storage is required to meet discharge criteria. CS modeling has indicated that a bioretention system, such as the group of installations currently being put in place in Philadelphia, is capable of treating the vast majority of annual runoff, with other controls needed only in atypically large storms. Using a realistic "design year," it is possible to project the behavior of a planter/trench system over annual rainfall distribution under a variety of conditions.

A limitation of the modeling presented here is that it does not fully account for evapotranspiration. If stone is replaced by structural soil, evapotranspiration becomes even more important. With both infiltration and evapotranspiration occurring, intercepted runoff both augments baseflow and ameliorates urban heat island effects. Because most evaporated moisture returns close by, even that is not lost.

Bioretention planters have much to offer. Philadelphia is relying heavily on them in its Long-Term Control Plan (LTCP) for reducing CSOs and will install \$50 million worth of these planters during the next 3 years.

System for Urban Stormwater Treatment and Analysis INtegration (SUSTAIN)

Dennis Lai, ORD, EPA, and Leslie Shoemaker, TetraTech

Dennis Lai provided an update on the development status of SUSTAIN, which was conceived in 2001 and contracted in 2003. In Phase 1, a prototype model was developed in 2005. Phase 2, involving system development, testing, and documentation, will be completed in 2009. The SUSTAIN Version 1.0 system will be released in October 2009. Phase 3 will involve targeted enhancements and case applications; the Version 2.0 release is targeted for mid-2012.

Leslie Shoemaker explained that SUSTAIN is a GIS-based framework to support decision making. It is designed to support practitioners in: developing cost-effective management plans for municipal stormwater programs, evaluating and selecting BMPs to achieve TMDL goals, identifying protective management practices and evaluating pollutant loadings for source water protection, and selecting cost-effective green infrastructure measures to help meet optimal flow reduction goals in CSO areas. Applications of SUSTAIN use a combination of “modules” and can easily handle multiple routing configurations. SUSTAIN focuses on the water, can accept land output from different models, can output to external receiving water models, and can be used for both small-scale and regional-scale optimization. The application of SUSTAIN to an example watershed was illustrated.

In summary, SUSTAIN is a comprehensive modular system that can incorporate emerging technologies. Modules are integrated under an ArcGIS platform to support data transfer and visualization. SUSTAIN operates at multiple scales, using an aggregate BMP method and tiered analysis, and it provides CS of sediment generation, erosion, and transport from urban surfaces to routing through BMPs. It incorporates a flexible cost module with base data compiled from various sources and the ability to add locally derived data. Optimization is based on user-defined criteria using two search algorithms.

The developers of SUSTAIN look forward to obtaining feedback from the user community and involving the community in the next round of development.

Discussion

Petronella Best asked which hydrological models are included in SUSTAIN. Leslie Shoemaker explained that SUSTAIN has a watershed module that is based on SWMM 5 and an internal hydrologic model for the BMP simulations, with the option to use two different infiltration calculation techniques.

Sandra Goodrow asked for clarification on how hydrologic input is used in SUSTAIN. Leslie Shoemaker responded that time series could be imported from previously generated models or that a SWMM application could be developed internal to SUSTAIN.

Kevin Magerr asked what resolution is needed for elevations in SUSTAIN. Leslie Shoemaker replied that the elevation grade depends on the local topography. In flat coastal plain areas, a 2-foot resolution is used. Data collected by counties are often used, as is IC mapping performed by local agencies.

Yusuf Mohamoud asked about the simulation step used in SUSTAIN and whether the model can be tested on real data. Leslie Shoemaker replied that the SUSTAIN developers like to use shorter-than-hourly steps if possible and that SUSTAIN has the flexibility to use different time steps. She added that the most recent round of testing of the model used real data and that efforts are being made to identify more such data to use.

Shirley Clark asked Bill Lucas what technique was used to acknowledge saturation in the model he had discussed. Bill Lucas answered that he used data for unsaturated flow conditions because saturated conditions are so rare that they are not of concern.

Shirley Clark asked about modeling for pathogens in SUSTAIN. Leslie Shoemaker replied that the model assumed first-order decay and KC* options. It is not a prescriptive behavioral model for bacteria. There is not enough information on how bacteria behave to allow for more specific modeling.

Monitoring Effectiveness

The Four Levels

Andy Erickson, University of Minnesota

Andy Erickson discussed the use of four levels of assessment of stormwater treatment practices (STPs). Before monitoring, it is important to ask: What are the goals? What resources (time, money, staff) are available? How many STPs need monitoring? Simple, quick, inexpensive assessment methods are needed and should be used when appropriate.

Assessment should be tailored to the desired goal, whether that is determining performance, construction due diligence, satisfaction of regulatory requirements, determining effects of changes in the watershed on hydrology and pollutant loads, or scheduling maintenance. Scheduling maintenance is the most important reason for assessment. Monitoring—the most complex and expensive form of assessment—is not needed in all situations. Other types of assessment should be used when they can provide suitable information.

Level 1 assessment, the simplest form, consists of visual inspection. Using a checklist, the assessor can systematically inspect STPs for problems such as sediment accumulation and bank erosion. It often is easy to spot STPs that are not working, such as a non-functional rain garden full of standing water. Visual inspection is the least expensive method, requiring only an inspector, a checklist, a clipboard, and a pen. A limitation of this method is that the results are not quantifiable. Level 1 assessment is well suited for scheduling maintenance.

Level 2 assessment consists of capacity testing. It involves point measurements to determine the capacity of an STP to perform its primary function. Unlike monitoring, it does not require equipment to be in the field at all times. Instruments are brought to a site only when an assessment is being conducted. Level 2 assessment is rapid and involves only a small volume of water, but the results must be spatially averaged, and the method does not quantify pollutant capture.

Level 3 assessment consists of synthetic runoff testing. In this approach, the assessors do not wait for rain; they add water to the system themselves, perhaps with some added pollutants. This can be accomplished quickly; in a month, it is possible to obtain as much quantitative data as would be collected in 2 or 3 years of storm events. It is not necessary to wait for rain. Synthetic runoff testing for some practices involves extensive equipment, however, as well as a nearby source of a substantial amount of water (such as a fire hydrant). Level 3 assessment may be limited to small practices and can only approximate loads.

Level 4 assessment is monitoring, in which equipment is installed permanently, and responses to real precipitation events are measured. Monitoring can measure most variables, and the measurements are direct. Monitoring, however, is the most expensive method of assessment, and it requires consistent maintenance and is time consuming. Moreover, if monitoring is not performed well, its results can be difficult to interpret.

Future research needs for STP assessment include: (1) refining testing methods for various STPs such as permeable pavements, ponds, and swales; (2) applying the four level approach at a watershed scale and estimating the cost savings compared to monitoring; and (3) comparing other testing methods to monitoring for inclusion of testing results in a BMP database.

Urban BMP Performance Tool: Overview/Uses/Future Development

Rachel Herbert, Office of Wastewater Management, EPA

Rachel Herbert described an EPA project to create a system to provide easy access to stormwater BMP performance studies. Many studies on stormwater BMP effectiveness have been conducted, but not all have been published. There has been no easy way for developers, MS4s, permit writers, TMDL staff,

watershed planners, and others to access all of the information. EPA wanted to create a new tool to make it easy to provide information to people. Key steps in development of the tool included collecting results and key supporting data from published studies and others that meet EPA criteria, designing easy-to-use search and sort options, developing a format to report pollutant removal and volume reduction information, and providing linkages to information (studies, statistical abstracts, design briefs) when possible.

Elements of the tool include educational “essays” (two-page fact sheets) on various topics, including understanding BMP performance, the importance of volume reduction, and the problems with “percent removals”; information from 220 studies and on more than 275 BMPs; and options that allow searching by pollutant groups or subgroups, BMP types, volume reduction, and keywords.

Rachel Herbert displayed illustrations of the online tool, demonstrating how it incorporates green infrastructure and giving examples of its output—a list of titles of studies, ranked by the quality of the study. If the user selects the title, general information, an abstract, and some specific data are provided.

Possible next steps for the tool, if funding is available, include adding additional studies, especially on LID and green infrastructure BMPs, developing an input page to allow researchers to enter their studies, outreach and marketing, and identifying other information gaps. Future research needs include: (1) filling data gaps (i.e., assessing infiltrating devices, assessing the consistency of study designs and parameters, collecting data from better quality studies to eliminate reliance on percent removal, assessing BMP performance at larger scales, and acquiring better information on BMP performance with regard to bacteria); and (2) moving beyond site-level planning to the neighborhood and regional/watershed scales. An updated BMP Performance Manual also has been developed; studies that follow the protocols and standards recommended in this manual will be added to the database.

BMP Performance Curves for the New England Region

Mark Voorhees, Region 1, EPA

Mark Voorhees presented a summary of a study that he and his colleagues conducted to evaluate BMP performance in the New England region and provided some perspective on why this study was performed and how Region 1 plans to use the results. The impetus for the project was a high-profile phosphorus TMDL that was developed for the Charles River in Massachusetts, an extremely developed 300-square-mile watershed that requires very large reductions in phosphorus. Much retrofitting will be needed to meet this TMDL, so there was a need to look at opportunities at existing sites where site constraints are present to determine the value of small-scale BMPs. Historical rainfall patterns also needed to be taken into consideration; New England has frequent rainfall but most storms are small. The effectiveness of BMPs in this setting needed to be investigated through CS. The performance curves that were developed for specific BMPs could be used to determine the BMP size needed for a specific percentage removal or vice versa, thus providing long-term cumulative performance estimates and eliminating the need for detailed modeling and evaluation in individual applications.

The development of the performance curves involved rainfall analysis and generation of time series of flow and quality using SWMM, which then were integrated into a model to simulate BMP performance. The model used was the BMPDSS developed in Prince George’s County, Maryland. The model included eight BMPs, three pollutants, and differing runoff quality representative of five land uses. It simulated long-term BMP performance and allowed for flexible site layouts.

Part of the process involved calibration of the model and testing it against actual data, including data from the UNH test site. The most commonly used types of BMPs were included, even though some do not perform well for phosphorus. It is hoped that the results of this study will provide a realistic idea of how various BMPs perform for phosphorus and encourage the use of some of the more progressive LID BMPs, especially infiltration systems. The calibration process included a hydrologic calibration to simulate runoff volume and quality coming into the BMPs, followed by a BMP calibration. The water

quality calibrations for the BMPs were performed using three events, followed by a CS of the monitoring process that UNH has carried out for these BMPs. There were noticeable tiers in BMP performance, with infiltration systems being the most successful. After calibration, performance curves were developed for total suspended solids (TSS), phosphorus, and zinc; it proved impossible to create performance curves for total nitrogen because insufficient data were available. In terms of retrofitting opportunities, it was promising to see that even small-sized systems and those with relatively low infiltration rates could achieve good removal performance.

As a follow-up on the project, EPA Headquarters funded Region 1 to develop a spreadsheet tool to automate reading the curves; this will be helpful in the permit process. Next steps include testing other BMPs as TMDLs are implemented and attempting to develop performance curves for nitrogen.

In the Charles River, RDA will focus on impervious areas in three upstream communities; locations with 2 acres or more of IC will have to obtain a permit and meet a TMDL. A very large reduction in phosphorus—50 percent or more—must be attained by these communities despite extensive development. The tool helped to evaluate the cost-effectiveness of a variety of approaches to phosphorus removal to allow optimization and helped to facilitate cooperation with the communities. The tool may be of value for the other 33 communities in the Charles River watershed as well.

Discussion

Shirley Clark commented that she liked the conceptual ideas of the four levels of assessment but that she was concerned about certain details, including the use of small cores, which may be sufficient only for ranking. In addition, she would be hesitant about simulating stormwater runoff for certain pollutants because of the differences between colloidal and dissolved metals. Andy Erickson agreed that these were important points and said that he hoped that future work, when funded, could focus on core testing and added pollutants. At present, only solids have been evaluated.

Bill Lucas asked Mark Voorhees for background on the source loading and characterization, so that it could be related to percent removal. Mark Voorhees replied that the percent reduction was based on loading, and that the TMDL is expressed in terms of load reduction rather than absolute numbers. The loadings in the UNH data resemble those of a commercial park and are therefore at the high end of the range. The values are expressed in percent reductions because this facilitates transferability. Bill Lucas said that findings from commercial sites, which have a high load of dilute runoff, may be conservative with regard to other types of sites. Mark Voorhees mentioned that one of the most challenging parts of the project was deciding to focus only on impervious area for the purpose of developing a reasonable number of curves. Also, in retrofits, many systems would be small and would be dealing primarily with flow from impervious areas. There is a need to continue the research, but estimates were needed to support the development of permits that require very large reductions in pollutant discharges. Curves may be refined in the future, but at least the estimates that have been made are better than taking median values from a database, which is what would have been done in their absence.

Zeyuan Qiu asked Mark Voorhees what constraints prevent near-100 percent removal. Mark Voorhees replied that larger storms will generate load from pervious areas, which is not reflected in the curves generated by the tool. This is a limitation resulting from efforts to keep the tool simple and usable. Thus, the curves may not be valid for particularly large storms. The effects of volume from pervious areas in large storms, however, can be taken into account in the design of BMPs.

Panel on Monitoring: Issues/Research Needs

Quantifying Pollutant Loading From MS4s Plus

Angus Eaton, New York State Department of Environmental Conservation

Angus Eaton told the participants that the stormwater program in New York State is addressing some very serious stormwater-related impairments. Seventy percent of the state's estuary acres and 30 percent of ponded freshwaters are impaired, with stormwater being the cause.

Phase 2 permits that came out in 2003 were renewed in 2008. When the permits were renewed, there was significant public interest; the public comment documents were 4.7 inches thick. Because there were so many comments, the state agreed to have 2-year rather than 5-year construction and MS4 permits. Draft permits should be ready soon.

The existing stormwater permit system is similar in some ways to the Vermont system. It includes statewide construction technical standards, parameter monitoring for Illicit Discharge Detection and Elimination (IDDE), and prescriptive BMPs and numeric reductions for watershed improvement with regard to phosphorus, nitrogen, and pathogens. The amount of parametric monitoring is limited because of time and cost considerations. The 2008 permits were criticized in some circles for limited monitoring. A positive aspect of the permits, in contrast, is their focus on watersheds. As the permits are renewed, additional TMDLs will be added to the permits.

In watershed improvement areas where the strategies require implementation of prescriptive BMPs, the New York is moving toward explicit numeric reductions in MS4s, with deadlines. Prescriptive BMPs include regulation of small construction sites; enhanced phosphorus removal standards; storm sewer system mapping; a retrofit plan and schedule; septic inspections, maintenance, and rehabilitation; targeted education and outreach; specific system maintenance requirements; turf management; pet waste management; and goose population management.

Key research needs, from New York's view, are among those listed in the NRC report: hydrologic and water quality processes for SCMs in different climates and soil conditions, runoff reduction effectiveness, effectiveness of nonstructural SCMs, and modeling. Monitoring research needs include: quantifying loads from MS4s, load reduction values of prescriptive BMPs and of non-traditional retrofits, effectiveness of newer practices, effectiveness of catch basin inserts, wet weather pathogen concentrations, generic media specifications and performance, and BMP failure.

Stormwater Monitoring in the Field. Do's, Don'ts, Why's, and How's

James Houle, UNH

James Houle began his presentation by noting that it is not possible for municipalities to monitor as extensively as researchers do, but some monitoring is needed. It is helpful to plan BMPs with monitoring as well as performance in mind to facilitate evaluation. Many of the devices and techniques used for monitoring have been adopted from the wastewater treatment industry, but additional challenges are present when they are used in the field, such as cables being severed by tree branches; damage from sediment in pipes; and damage or interference from cold weather, insect infestations, bird droppings, and animals chewing on wires and cables. Equipment that is both tough and economical is needed. Sometimes, the lowest-cost equipment is not sufficiently durable to function well in the stormwater monitoring environment. Monitoring devices may need to be heated to ensure correct performance in cold weather.

Concerns that automated samplers might produce bias have been shown to be unwarranted in an experiment in which results obtained from automated sampling were compared with those obtained manually. Very good correlation between the analytical and actual results was obtained. Samples can be split so that different portions can be analyzed for different contaminants.

For flow-weighted samples where the same monitoring equipment is used to measure influent and effluent, event mean concentrations (EMCs) can be very useful and conservative with regard to potential errors in flow measurement. For TMDLs, where mass balance is critical, accurate flow monitoring is of utmost importance.

Monitoring Stormwater Management Controls: Are They Still Doing What We Think They're Doing?

Mike Borst, ORD, EPA

Mike Borst began his presentation by pointing out that billions of dollars are being invested in green stormwater management, but it is not possible to provide assurances that the stormwater controls perform as intended in the long term. He and his laboratory want to advocate development of a set of measurements to confirm that stormwater management practices do what they are assumed to do. Monitoring similar controls across multiple sites will enable pooling results to create a broader understanding of the performance of the specific tools under differing conditions and of performance changes with age. Compiling results from multiple sites will allow the development of better conclusions. The NRMRL uses a unit management approach, which is not necessarily as easy as is often believed. Effective monitoring controls need to be taken into account during the design and construction stages of a project, with instrumentation, measurement capability, and access designed into the system. It is possible to obtain better measurements faster and at lower cost if the ability to measure is built into the system.

In determining what to measure and how often, NRMRL advocates an approach that parallels the Transportation Research Board's (TRB) roadway evaluation model. Multiple individual case studies are combined into a larger design, allowing statistical analysis to be performed on the collective results. Research starts at the bench scale, followed by pilot projects before projects are implemented in the field, because it is better to make mistakes at smaller scales; this saves time and money in the long run.

Flow and volume monitoring are good starting points for the process. Results to date indicate that selecting LID and green stormwater controls—as is being done in Philadelphia—can lead to a net benefit in meeting goals, while saving money at the same time. Long-term planning under consent decrees and other agreements enables documentation of performance and changes in performance.

Discussion

Eric Perkins asked whether there is a consensus on what type of monitoring should be required for the new round of MS4 permits that will require significant retrofits. Angus Eaton replied that monitoring requirements are not being included in New York's MS4 permits, although annual assessment is required, as is some type of modeling to verify performance on a 5-year basis. Ultimately, ambient monitoring will be the way to confirm the effectiveness of all BMPs, not only retrofits, and it will likely be performed by watershed groups or regulatory agencies.

Andy Erickson said that in Minnesota, there is a strong push to include standardized visual inspection in the next permit cycle or the one after that. This will enable comparison of findings across the state to identify where additional work is needed.

Rob Roseen commented about the goals for BMP performance monitoring. Monitoring may be best left to locations where a site can be highly instrumented. For permitting, wet weather flow monitoring should be required. For overall BMP assessment, visual inspection may be sufficient in many cases. He asked Mike Borst to explain his ideas for structured research more fully. Mike Borst responded that bioinfiltration and rain gardens are key because they are so widely accepted. Discussions with municipalities are in progress in an effort to initiate monitoring activities. Municipalities that are under consent decrees are not fighting back hard; they want to comply but need guidance on how to do so.

Dale Manty asked about assessment of stormwater control systems above groundwater, noting that bioretention systems above aquifers may have mixed performance. Mike Borst answered that the quality of water that infiltrates is being assessed. He noted that Long Island, New York, has underground injection wells because of the fear of saltwater intrusion. No contaminant load is evident in most locations.

Wrap Up

Maureen Krudner summarized the session by noting that the following key points had been made:

- ✧ It was stated several times that bacteria are an issue, although there are bacterial TMDLs.
- ✧ Several speakers discussed BMP effectiveness and water quality downstream.
- ✧ Reliance on percent removal as an effectiveness measure is decreasing.
- ✧ There is a need to define wet weather water quality standards.
- ✧ Quite a few tools and models have been developed; it would be helpful to obtain support to compile them in a more useful way.
- ✧ Costs are an important issue, and they will be discussed in more detail at tomorrow's session on economics.
- ✧ Monitoring has its place, but it must be planned in advance to be done well. For MS4s, broader assessment methods may be suitable.

Poster Session

A poster session was held on the evening of Wednesday, October 21.

Thursday, October 22, 2009

Morning Session

Economics of Stormwater Management

Moderator: Hale Thurston, ORD, EPA

State of Research Presentations

Overview

Economics of Stormwater Runoff Management

Hale Thurston, ORD, EPA

Hale Thurston began his presentation by stating that environmental economics boils down to two basic elements: valuation issues and market mechanisms and incentives (MM&I). Valuation relates to cost-benefit analysis and green versus gray infrastructure. Municipalities would like to see benefits in exchange for costs, but benefits are not as easy to quantify as cost. It is difficult to compare the benefits of newer techniques to those of traditional gray infrastructure. MM&I involves methods of getting people to do the right thing, usually through a mixture of “carrots” and “sticks,” to overcome a market failure. Much of the property affected by stormwater runoff is private property, so mechanisms must be devised to motivate the owners of the property to take action. Examples include auctions, tradable credits, and fee rebates (if stormwater fees are high enough, a rebate can be provided for those who install effective

stormwater controls). Each of these approaches works in different ways on commercial property versus residential property.

In the Shepherd Creek pilot project discussed yesterday, the lack of a regulatory “stick” was a major challenge. The use of a voluntary reverse auction as a “carrot” was attempted instead. In terms of benefits (quantity of stormwater retained), it has been shown that an auction can be as effective as payment and that both are more effective than education. The costs of the auction or education were less than the cost of payment; it had been proposed that the stormwater runoff problem be solved in the Shepherd Creek area through construction of a large tunnel, but the use of voluntarily installed green infrastructure was implemented instead.

Two of the speakers in this session, Andy Erickson and Lisa Hair, will discuss valuation issues. The other three, Abby Hall, Franco Montalto, and Paula Estornell, will discuss MM&I and various incentives for adoption.

Cost Effectiveness and Comparison: Traditional Versus LID Controls

Cost, Effectiveness, and Maintenance of STPs

Andy Erickson, University of Minnesota

Andy Erickson began his presentation by pointing out that different STPs have different functions. A dry pond provides flood protection only; a wet pond provides both flood protection and pollutant capture; a rain garden provides both of these benefits plus volume reduction. The rain garden, however, may cost more than either of the other STPs.

Sufficient data exist to compare the construction and maintenance costs, land area, and effectiveness of seven STPs: dry ponds, wet ponds, constructed wetlands, bioretention filters (rain gardens), sand filters, infiltration trenches, and swales. For wet ponds, the unit construction cost is generally higher for lower water volume, indicating an economy of scale, but there is much scatter in the data. Most other practices show similar patterns, except that bioretention filters do not show economy of scale. Most practices are in a similar range in terms of unit construction cost as related to water volume.

When maintenance cost is compared to construction cost, most STPs show economy of scale, but again there is much scatter in the data. Exceptions to the general pattern are infiltration trenches, where the data show the opposite of an economy of scale (the findings may be artifacts caused by a few poorly installed and maintained STPs), and sand filters, which show no economy of scale (a flat relationship), likely reflecting material costs (a few inches of material need to be scraped off periodically).

A survey in Minnesota and Wisconsin on maintenance of 10 types of STPs showed the highest median maintenance cost for porous pavements and the highest maximum maintenance cost for underground sedimentation devices. Costs were lowest for surface sand or soil filters, underground filtration devices, and infiltration basins or trenches.

Land area requirements also need to be taken into account in evaluation of the cost of STPs. Some practices, such as filter strips and swales, require much more land than others, such as sand filters and infiltration trenches.

Data indicate that bioretention filters, sand filters, infiltration trenches, and filter strips/grassed swales are the most effective stormwater controls for TSS, whereas bioretention trenches show the most consistent effectiveness for total phosphorus; some practices show more spread in effectiveness than others, and data are expressed as percent removal because these are the only values available.

Calculation methods are available for construction cost, maintenance cost, expected pollutant capture, estimated land area requirements, and cost effectiveness, although substantial uncertainty is present in

most of the data. Nevertheless, reasonable estimates can be generated and compared for alternative STPs. An important point to remember is that maintenance costs are significant. They may equal construction costs after 10 years for a \$10,000 installation and may equal construction costs after 20 years for a \$100,000 installation.

Future research needs include: greater accuracy and precision to reduce uncertainty; better documentation of costs, especially maintenance costs; quantification of relationships between maintenance and performance; and expansion of the recent research topics survey created in Minnesota and distributed by EPA to obtain nationwide results.

Carolyn Hayek asked whether any of the numbers included in this presentation incorporate frequency and duration of maintenance activity. Andy Erickson replied that they did not, except for the Minnesota/Wisconsin maintenance survey.

Dale Manty asked about cost as a deterrent to acceptance of innovative water treatment systems. Who covers the cost is an issue. How do costs vary across acceptance thresholds? Andy Erickson replied that there is a need to work differently and find different solutions. Newer practices may turn out to be less expensive than traditional ones as they are refined and become more effective.

Lambro Boudrodimos inquired about pollutant capture. When removal rates are presented, how should it be explained to the public where the pollutants went? Andy Erickson responded that most of the pollutants do not go away, except for a few that volatilize (and nitrogen, if it is denitrified). Phosphorus, sediments, and metals are still in the STP; they accumulate over time and need to be harvested eventually. Some pollutants, such as chloride, may infiltrate into groundwater.

A participant asked about the relationship between the frequency of maintenance and enforcement actions. What drives people to maintain an STP as they should? Andy Erickson replied that frequency of inspection and maintenance often is limited by budget and staff. Public works departments may perform maintenance on a stormwater control only if it is flooding or has become an eyesore. Better methods need to be developed to ensure that maintenance is performed at appropriate intervals.

Review of Water Environment Research Foundation (WERF) Stormwater Management Practice Cost Tool/Case Studies of Cost/Benefit Comparisons

Lisa Hair, OW, EPA

Lisa Hair explained that she would discuss a current project and would also display some cost estimating tools developed for EPA by WERF that can be used by municipalities, engineers, and developers to compare stormwater controls.

The current project involves collecting information on how municipal entities evaluate the costs and benefits of green infrastructure, such as the method used in the project in Philadelphia discussed yesterday. The case studies compiled in this way will be combined into a publication. Two such case studies are described below, and Lisa Hair encouraged participants in the workshop to submit others.

- ✧ One case study involves Los Angeles County and the harvesting of rainwater for flood control. Los Angeles obtains its drinking water from distant sites at great cost and experiences severe water shortages, but simultaneously, large quantities of rainwater are lost in the county because of the use of concrete-lined channels to prevent flooding. In the Sun Valley subwatershed, where pipes had never been installed and repeated flooding was a problem, an innovative alternative was chosen: on-site treatment and infiltration. The project was very successful. Five years later, it is still considered a model for stormwater management. As a consequence of the success of this project, Los Angeles County has now taken a new approach to all of its subwatersheds, making an effort to devise ways to capture water for infiltration or re-use whenever retrofitting is carried

out. Also, Los Angeles County Flood Control now has become the Los Angeles County Water Management District, allowing for more holistic management of water.

- ✧ A second case study comes from St. Paul, Minnesota, in the Capital Region Watershed District, a highly impaired, 41-square-mile interjurisdictional watershed with flooding problems and high IC. The conventional solution to the flooding problem would be to add a new large pipe through a park in the area, which would severely disrupt the park and would not improve water quality in the highly impaired Lake Como, one of the four lakes located in the watershed. An infiltration alternative was evaluated—installing infiltration trenches, rain gardens, and an underground storage and infiltration facility. The new installations reduced flooding and improved water quality, and they were found to be less costly in the long term than the more traditional solution.

The costing tool project was just completed this year. It consists of tools that designers can use to estimate the impact of several LID techniques. These tools are free and can be ordered from WERF through the Internet; they cannot, however, simply be downloaded from the Internet.

It has become a standard practice in asset management for wastewater and drinking water to review the net present value of capital project alternatives so that the municipality can provide the best value to its citizens. There are different ways to evaluate the capital cost of a project. Developers usually are interested in the short-term cost because that is most relevant to them. Owners are more interested in a longer-term estimate. A third possibility is the triple-bottom-line approach, which takes into account economic, social justice, and social equity components, which is the way projects are evaluated in terms of their overall impact for society.

Using the tools can help people to present business cases for particular stormwater controls, but the process is not necessarily as cut-and-dried as it may seem. Net present value is not the ideal measure for some purposes because it does not reflect future costs. Also, some of the data used in the development of the tools, especially for the newer stormwater controls, are limited. For some types of stormwater controls, such as rain gardens, there may appear to be extensive data in the literature, but in actuality multiple authors are repeatedly citing the same few studies. In other instances, the available cost data are not very detailed (as in the case of green roofs), data may be derived from only one manufacturer (as in the case of in-curb planters), or data may be very limited (as in the case of cisterns).

The tools can easily be modified by the users; they are in the form of Excel spreadsheets and can be changed just by unprotecting the sheet. Lisa Hair urged users of the tools not to just consider the cost of particular controls but to compare the costs of several different forms of management and the cost of doing nothing, as well as the benefits provided by different green techniques, which are not taken into account in the tool.

Ron Landy commented that about 10 years ago, an ORD green roof project found that some European companies were more advanced than U.S. companies in the development of this technology but their products were discussed only in foreign-language trade journals. Lisa Hair said that no attempt had been made to obtain data from non-English language sources in her study, but that it would be helpful to have those data because the use of green roofs is more common in Europe. Nevertheless, the quantity of data for green roofs included in the costing tools is sufficient to be useful.

Ed Frankel asked whether the case studies Lisa Hair discussed considered mounding. Lisa Hair noted that in Los Angeles County, where the water table is low, mounding is not an issue. In other settings, however, the potential for contamination needs to be considered.

Financing New Development and Retrofit Programs

Funding and Incentives

Abby Hall, Office of the Administrator, EPA

Abby Hall discussed funding mechanisms for stormwater controls and non-regulatory incentives. When developing green infrastructure, it is important to think on three scales—site, neighborhood, and watershed. More information can be found in the green infrastructure section of the EPA Web site.

Funding options include stormwater fees, local taxes and fees, grants, and the Clean Water State Revolving Fund. Stormwater fees traditionally were based on water use, but there has been a shift to impervious-based billing. Under the old system, a high-rise apartment building on a small lot would have paid a much higher fee than a large parking lot; under the new system, the parking lot, which has a larger impervious footprint, would pay more because it is assumed that the larger amount of IC means a greater contribution to stormwater runoff. Stormwater fees are not taxes—an important point in some jurisdictions such as Washington, DC, because it means that they can be applied to government buildings. The fees are managed by a utility or existing agency.

Other taxes and fees, such as developer fees, fees-in-lieu, impact fees, property taxes, and sales taxes, can also be used to finance stormwater projects. Grants from EPA, the Department of Housing and Urban Development, the Federal Highway Administration, or the U.S. Department of Agriculture's Forest Service may be available, but communities should not count on them to finance their stormwater programs; a sustainable local source of funding is needed. Another source of funding, the State Revolving Fund Program, received a major boost under the American Recovery and Reinvestment Act (ARRA). Applications for the ARRA funds greatly exceeded the amount available, indicating the strong interest of many communities in green infrastructure.

Incentives include stormwater fee discounts (if the property owner installs measures that reduce or disconnect IC, the fee is reduced), development incentives, rebates and installation financing, stormwater regulation, and awards and recognition programs. Stormwater fee discounts have been used successfully in Portland, Oregon; Philadelphia, Pennsylvania; and Toledo, Ohio, among other communities; they are particularly effective for commercial rather than residential properties. Development incentives, which often include expediting permits if effective stormwater controls are included in the design, have been used successfully in Chicago, Philadelphia, Portland, and Seattle. Rebates have been used in several communities to encourage downspout disconnection, rain barrel installation, green roofs, and other measures. Stormwater regulation is more about disincentives than incentives. Fewer regulations may be imposed in already developed areas to encourage development there rather than in areas where development would decrease greenfields. Awards and recognition programs draw attention to effective stormwater control methods. Community information programs may provide social marketing incentives. For example, Portland has online maps indicating where green infrastructure has been installed and identifying contractors who do green infrastructure work. This allows residents to see what their neighbors are doing and to link with contractors.

Paula Estornell asked how Abby Hall found the cities she chose to study and whether she will return to them later to assess how much the newer approaches are spreading. Abby Hall replied that the original intent of the project was to examine the best stormwater regulatory programs, either performance-based or prescriptive, throughout the country, and that a dozen communities were chosen this way. Many people said, however, that regulations were not necessarily the main driving force for green infrastructure, so the focus of the project was shifted to include other communities in which stormwater control innovation was being driven by other types of policies as well.

Dale Manty noted that large-scale water management projects in many cities, such as underground concrete bunkers, are paid for with public dollars. How do cities like Philadelphia, which places an emphasis on green infrastructure, compete in promoting these systems? Abby Hall responded that

Philadelphia has done a great job of identifying the cost savings of green infrastructure and how a combination of green and conventional methods has advantages (the green infrastructure decreases the demand on conventional systems, thus decreasing the need for maintenance, replacement, or expansion). Philadelphia can demonstrate that it is thinking smart in terms of money, as well as meeting regulations and improving the environment.

Stu Kerzner, who works with the Philadelphia water department, said that it is important to keep in mind that Philadelphia has a combined sewer system. During a storm, a mixture of sewage and stormwater flows into the Delaware River and smaller streams, violating water quality standards. Not violating these standards is a major incentive. Abby Hall said that Philadelphia has a sewershed plan, which indicates where CSO overflows occur and allows the city to focus its corrective efforts in the most affected locations.

Andy Dinsmore commented that it is important to use the types and hybrids of approaches discussed today as examples for smaller communities. Regulation is designed to keep things from getting worse, but other approaches are needed to help communities return to a sustainable condition. Abby Hall noted that future research needs include volume reduction and cost savings for the public; better data are needed on these topics.

Planning and Implementation Models for LID Retrofits

Franco Montalto, Drexel University

Franco Montalto discussed LID retrofits in urban areas, where the limited surfaces available for installation of new stormwater controls present a major challenge. Achieving wide-scale implementation of LID in developed landscapes requires collaboration by governments, developers, regulators, and individuals.

One challenge is urban heterogeneity. Urban settings are a mixture of public and privately owned lands, owner-occupied and rental units, and topographic and engineered watersheds. Many landscapes and soils are highly disturbed, with underground pipes and other structures present. A second challenge is participation. Residents in an area may be excited about the benefits of green infrastructure, but the residents often are not the property owners and do not have control over whether a green roof, rain garden, or other BMP is installed where they live. Community groups may play a positive role or may oppose any kind of further development. Timing is a third challenge. Utilities may need to meet regulatory requirements quickly, and the green approach may take too much time. Priorities of different agencies may conflict. For example, in New York City, there is an inconsistency between local sustainability plans and the water utility's plans. A fourth challenge is decentralized quality control. In an urban environment, there are "lots and lots of lots," each of which may be managed differently.

Widespread implementation of LID will not occur without public support. LID typically costs more; for example, life cycle costing estimates indicate that in terms of: (1) total initial cost, (2) annual operation and maintenance cost, and (3) total present value, a rain garden is more expensive than standard turf occupying the same area, and a porous sidewalk is more expensive than a standard one. Potential LID policy options include the water utility paying for the entire life cycle cost of LID; the water utility paying the initial cost only, with the property owner paying for operation and maintenance; the water utility paying for operation and maintenance of LID installed by property owners; and other options. Choosing the best policy requires an understanding of stakeholder attitudes. Uncertainty about public attitudes can make LID planning difficult.

Franco Montalto and his colleagues have been working on an LID planning tool that considers multiple uncertainties that influence the effectiveness of a policy instrument or investment, including adoption rates, precipitation patterns, other constraints, and runoff capture rates. The tool, called LIDRA 1.0, incorporates some basic assumptions, such as that the water utility would pay property owners the difference between the life cycle cost of standard and LID options; that all LID systems would be

adequately maintained; and that LID implementation would occur within relevant regulatory time frames. Application of this tool to New York City data on runoff reductions and sewer overflows generated interesting results regarding CSO overflow triggers and cost effectiveness.

LIDRA 2.0, which is in development, will be a more robust open-source Web tool allowing the user to compare the cost effectiveness of alternative LID policies using risk concepts. It incorporates more sophisticated methods of computation, and its required user inputs include information from focus groups or surveys. LIDRA 2.0 can provide aggregated risk analysis results on LID cost effectiveness, showing all of the uncertainty in the estimates. Ongoing work with LIDRA 2.0 includes continuing model development and application case studies in New York City; Newark, New Jersey; and the Hudson River Valley. Feedback from potential users of the tool would be welcome.

Brownfields to Greenfields

Paula Estornell, Region 3, EPA

Paula Estornell discussed EPA's brownfields mission. Brownfields are defined as property contaminated or potentially contaminated by hazardous substances, pollutants, contaminants, petroleum, or controlled substances, such as abandoned industrial, manufacturing, commercial, or retail sites; dump sites; mine-scarred land; abandoned gas stations; and buildings contaminated with lead paint or asbestos. EPA's Brownfields Program empowers states, communities, and other stakeholders in economic redevelopment to work together to assess, safely clean up, and sustainably reuse brownfields. Superfund sites and federally owned land are not eligible for brownfields funding. The Brownfields Program is relatively new; it began in pilot communities in the 1990s and received substantial funding in 2002. Through the program, EPA provides grants to communities to assess and clean up sites, funds state programs, provides technical assistance, conducts research, and provides research grants and supports academic partnerships.

A goal of the Brownfields Program is actively to change brownfields into greenfields. Because much infrastructure already is present, every acre of brownfields developed saves 4.5 acres of greenfields. EPA brownfields funding is intended as seed money and liability relief for developers. The dollar amounts provided by EPA usually are not large, but can be leveraged with private money from other sources.

Because the Brownfields Program involves retrofitting in urban areas, there is a connection between this program and stormwater management. Land cover plays an important role in wet weather runoff. The creation of green urban infrastructure can improve stormwater management.

There can be some problems and conflicting priorities in the greening of brownfields, including the following:

- ✧ *Health and safety.* Should the natural hydrologic cycle be promoted (possibly allowing contaminants to find their way into groundwater) or should contaminated soil and groundwater be capped? Should brownfields be redeveloped for parks and recreation, or should this be avoided to reduce the risk of human exposure to contaminants?
- ✧ *Economic problems.* Should the use of green infrastructure be promoted or should the focus be on new development and the building of the tax base that results? Are conservation easements desirable or should brownfields be developed in ways that create jobs and promote active business districts?
- ✧ *Community acceptance.* Will people accept the idea of revitalizing the urban core in place of the traditional sprawl on greenfields? Will the idea of working with nature, rather than controlling it, be accepted?
- ✧ *Regulatory problems.* Will conflicts develop between policies designed to maintain or restore water quality and those intended to promote economic development?

The success of the Brownfields Program cannot yet be assessed; however, some communities, notably Cleveland, Ohio, which has much heavily blighted vacant land, are attempting to develop brownfields in ways that will allow the community to derive quantifiable benefits from vacant property and link natural and built systems in ways that improve quality of life, health, and the environment. Research needs include the water quality benefits of brownfields revitalization, benefit-cost analysis of gray versus green infrastructure; impact analysis of collaborative sustainable development endeavors; and sustainability metrics for land revitalization.

Discussion

Carolyn Hayek commented that the general response to soil contamination is to cap and asked whether infiltration is immediately ruled out. Paula Estornell replied that people are talking about phytoremediation, using plants that take up contaminants. Whether this approach would be successful depends on the ultimate use of the land. The greening of brownfields is not always viable. Abby Hall noted that in a project in Chicago, excavated contaminated soil was replaced with large rocks, creating a holding chamber that helped to prevent stormwater overflow. Paula Estornell noted that the bottoms of swales, rain gardens, and other installations can be lined to prevent the escape of pollutants. Franco Montalto reported that in a project in Philadelphia, questions arose when people wanted to use a revitalized but potentially contaminated area to grow food; to avoid possible health issues, above-grade planters were installed instead.

Ron Landy commented that health and safety are primary concerns, but that the focus usually is on the negative aspects. The positive side of safety also should be considered. For example, trees are associated with lower crime and they reduce particulate matter levels in the air, thus improving air quality. Paula Estornell replied that more research is needed on the benefits of natural systems. One study associated the use of green roofs with fewer emergency room visits because of decreases in asthma and heat-related illness, for example. Paula Estornell noted that a good body of research on multiple benefits is developing. Franco Montalto reported that the New York City Department of Parks and Recreation is planting a large number of new trees and is conducting research, including health-related research, in conjunction with this project. Lisa Hair said that two tools, CityGreen and ITrees, can help quantify the benefits of trees. Paula Estornell observed that the risk in revitalized areas is much lower than the risk present before revitalization.

Allison Roy asked Andy Erickson whether multiple benefits can be incorporated into cost/benefit analyses. Andy Erickson responded that quantifying some aspects would be challenging, but that it would work. Abby Hall commented that part of EPA's goal is protecting human health. Working with partners outside of the Agency, including the Centers for Disease Control and Prevention and county public health departments, can help in achieving this goal.

Melissa Evers commented on community acceptance, noting that education is needed before a community can make an informed decision about what it will accept. Abby Hall noted that a small but key part of pilot projects is educational signage to inform the community about what is being done. Franco Montalto said that in his work in New York City, efforts have been made to hold focus group meetings before implementing pilot projects, but that the people attending the meetings often were not the decision makers. They were tenants who had no control over what was done to the property they occupied. A mail-in survey conducted as part of his research was deliberately conducted before any educational efforts were made so that education would not bias the results of the survey; the survey participants, however, may not have been representative of the area's population because a disproportionate number of participants had above-average household incomes.

A participant asked whether K6 grants are available only to universities. Paula Estornell responded that they are available to nonprofit organizations and universities but not to states.

Art McGarity asked whether the LIDRA models are capable of prioritizing different LID technologies and whether optimization is used in these models. Franco Montalto said that LIDRA 2.0 was designed as a prescriptive tool, but different options could be compared. If additional funding is obtained, it may be possible to further develop the model so that it can be used for optimization.

Charles App asked Abby Hall whether she had any information on funding and financing in smaller communities. Abby Hall replied that she did have some information on communities with populations of approximately 20,000 to 30,000, but that there was a need to obtain data from rural areas. Andy Erickson pointed out that in Minnesota, voters actually increased taxes for water quality projects; these funds will be used in rural as well as urban areas.

Workshop Wrap Up: Summary of Identified Research Needs

Session Moderators

The moderators of each workshop session presented summaries of research needs identified during their sessions.

Charles App, moderator of the session on watershed assessment and ecological response, summarized his perception of the session as follows:

- ✧ As IC increases, an impact on the ecosystem is observed. There was considerable discussion about thresholds, which need to be reconciled with endpoints. Matt Baker reported finding significant declines in taxa richness at very low levels of IC; work needs to be performed to reconcile this endpoint with the results of other research.
- ✧ There is a need for comprehensive pilot/demonstration studies on the effectiveness of stormwater controls in restoring impaired watersheds. One important question to answer is whether they can be returned to a condition that would allow swimming and fishing. Another issue that should be explored in pilot projects is the cost of implementation. Pilots should address the issues of relative cost effectiveness of different approaches and how best to finance them.
- ✧ Social factors need to be included in the work performed in the stormwater field.
- ✧ Groundwater contamination is a lingering concern, especially because many approaches to stormwater management incorporate infiltration. It is important to ensure that long-term groundwater contamination problems will not result from stormwater management measures. Chloride, in particular, is an issue.

Kevin Magerr, moderator of the session on innovative stormwater controls, summarized the identified research needs as follows:

- ✧ With regard to innovative stormwater controls, important topics for research include SCM performance and infiltration and evapotranspiration.
- ✧ In terms of BMP monitoring and maintenance, the development of pollutant-based maintenance schedules should be explored.
- ✧ Opportunities for stormwater retrofits in urban areas, brownfields, and highway corridors should be investigated. It also is important to study ways of establishing incentives for retrofits, perhaps by incorporating them into permits.
- ✧ The collaborative model should be investigated as a way of approaching the social barriers to implementing stormwater controls.
- ✧ The interface between green and gray infrastructure needs further investigation.

Maureen Krudner, moderator of the session on NPDES stormwater permitting, identified the following research needs:

- ✧ *Cost.* How should stormwater management be paid for?
- ✧ *Need for wet-weather standards.* Current standards were designed for dry weather, not for precipitation-driven events.
- ✧ *Credit for BMPs.* In developing stormwater permits, credit needs to be given to those who install stormwater controls.
- ✧ *Keeping watersheds healthy.* The novel idea of focusing on maintaining the quality of healthy watersheds rather than devoting attention only to impaired watersheds should be investigated further.
- ✧ *Retrofits.* Many questions need to be answered. How should retrofits be designed? What are the best sites? How can credits be given? Are retrofits the only way to reduce existing loads?
- ✧ *Assessment of effectiveness.* What level of assessment is warranted in a given situation?
- ✧ *Bacteria.* Much more needs to be learned about bacteria as stormwater contaminants.

Paula Estornell, substituting for Hale Thurston, summarized the research needs discussed during the session on the economics of stormwater management as follows:

- ✧ The research on the cost, effectiveness, and maintenance of STPs described by Andy Erickson needs to be continued and updated. Examination of maintenance costs is especially important.
- ✧ The costing tools described by Lisa Hair need to be made more robust.
- ✧ Incentives are an important issue, as is their application to smaller communities.
- ✧ With regard to the models for LID retrofits described by Franco Montalto, it would be worthwhile to review the research from the opposite perspective (i.e., given a certain amount of money, what LID can be installed?).
- ✧ Much more needs to be learned about the greening of brownfields, in terms of such issues as health and safety, economics, and public acceptance.

Afternoon Session (EPA Personnel Only)

RSIT: Next Steps and Collaborative Training, Part 2

Facilitators: Walt Galloway and Paula Estornell

A meeting for EPA personnel only was held on the last afternoon of the workshop for the purpose of initiating an RSIT on stormwater management. As part of their roles as facilitators for this meeting, Walt Galloway and Paula Estornell presented a summarized version of EPA's collaboration training.

It was noted that OW could be and probably should be involved in the proposed RSIT but that no OW personnel were present at this workshop because of a conflict with an OW event.

As discussed by Ron Landy earlier in the workshop, and as covered in more detail in a handout on the RSIT distributed in the workshop folder, the RSIT concept was developed and presented at the 2007 Regional Science Summit. The goal of the RSIT is to: bring together interested regions, program offices, and ORD components; identify the highest priority research needs (through discussion with academics

and other external partners); and develop a multidisciplinary collaborative research plan. The plan would address the identified research needs using the full range of ORD capabilities. The proposed RSIT on stormwater to be developed at this meeting is the first of its kind.

As preparation for the detailed discussions, Walt Galloway and Paula Estornell summarized information on the keys to successful collaboration, derived from a synthesis of the findings of top scholars and the EPA model for collaboration, as follows:

- ✧ Vision and Purpose
 - A shared environmental problem/clearly defined purpose
 - Organization support through written agreement
- ✧ People
 - Committed leader/full representation
 - Functional relationships
- ✧ Information/Resources
 - Informed process (empirical data)
 - Funding
- ✧ Communication/Dialogue
 - Regular contact
 - Celebrate success

Personal traits that are key to building successful collaborative efforts include the ability to listen, excellent communication skills, the ability to build and maintain relationships, strong technical knowledge, a win/win attitude, and celebrating success. In a collaboration, the goal is to integrate interests and work jointly.

Collaboration works best if documented in a written agreement that gives the purpose of the collaboration (in this instance, a multidisciplinary team to solve stormwater problems), roles and responsibilities, process, timeline, desired outcomes, and performance measures for the collaboration.

Following the presentation on collaboration by Walt Galloway and Paula Estornell, the attendees discussed the first steps in implementing a Stormwater RSIT. Key discussion points included the following:

- ✧ Charles App observed that a group of motivated people from three regions and ORD, all with a shared interest in stormwater issues, had just collaborated successfully in the planning of this RSW. He suggested that the same planning group, with a few additions, form the nucleus of this RSIT. In general, the group agreed with this concept, although it was noted that someone from OW should be included even though OW had no involvement with the RSW.
- ✧ Ron Landy raised the issue of the size of the RSIT, noting that it is important to include representatives from all interested groups but that it can be difficult for very large groups to work together. After some discussion, it was agreed that a group of approximately 12 people would be most workable. Ron Landy also inquired whether anyone who was missed in the planning of the RSW should be included now.
- ✧ Paula Estornell commented that people in the Superfund and Brownfields programs are doing work directly related to stormwater issues. She noted that stormwater is not an isolated issue; it is directly related to land management, sustainable systems, and green infrastructure.
- ✧ Dale Manty asked whether the RSIT should include only Regions 1, 2, and 3 or whether other regions also should be involved. In addition, he suggested the possible involvement of some university grantees. Walt Galloway clarified that only EPA personnel can be involved in the

RSIT for now because information confidential to EPA, such as budget matters, may be discussed. Those from outside EPA can be called upon to contribute their expertise and views but cannot be RSIT members. The group discussed the possible inclusion of EPA personnel from other regions but decided that it would be best to include only Regions 1, 2, and 3, at least at first. These three regions are accustomed to working together and have many common interests. Moreover, Region 3 is the lead region for water and therefore has a high level of commitment to water-related issues. The level of commitment is not as great in some of the other regions. Charles App pointed out that most of the other regions are not as interested as Regions 1, 2, and 3 in providing input to ORD with regard to water-related research planning.

- ✧ It was noted that although some members of the RSIT should be stormwater experts, not all need to be. People with experience working with ORD should also be included. The Regional Science Liaisons from one or more of the three regions might be particularly valuable RSIT members.
- ✧ To help in identifying possible RSIT members from ORD, Walt Galloway noted that each National Laboratory has an Assistant Laboratory Director for water, who reports to the Deputy Assistant Administrator for Science. There also is a National Program Director.
- ✧ Andy Dinsmore raised the issue of whether someone from the enforcement side of EPA—that is, the Office of Compliance and Enforcement Assurance (OECA)—should be included in the RSIT, but this idea was not discussed further.
- ✧ Maureen Krudner and Walt Galloway emphasized the need for the RSIT to have a leader or possibly two co-leads. Others agreed, but no leader was chosen at this initial meeting.
- ✧ Several members of the group expressed strong concerns about support for the RSIT from senior and middle management. Although the RSIT is being formed at the request of senior management, it is unclear whether managers will be willing to allow RSIT members to commit time to the RSIT. Marie O’Shea noted that management support in Region 3 may be greater than that in Regions 1 and 2, where other priorities may take precedence. The amount of time that RSIT members will need to devote to the RSIT is uncertain, as is the possible need for support staff time. Managers have not been told that the RSIT will be a long-term commitment. Charlie App expressed the view that participation in the RSIT would not require much of the members’ time, but other participants were uncertain whether this was correct.
- ✧ It was suggested that generating a white paper might be an important early priority for the RSIT because such a document could be used to help promote the RSIT to senior management.
- ✧ Audrey Levine commented that the RSIT needs a goal statement to help “sell” it to management and others. Communication to non-participants is important; RSIT members will need to be creative in engaging people.
- ✧ The importance of having deadlines was discussed. Participants made the point that the RSW was successful in part because it had a natural deadline—the dates of the workshop. It is important to have deadlines and endpoints; without them, dialogue tends to go on forever.
- ✧ The need for regular communication within the RSIT was discussed. Although a Wiki or chat room would be valuable, face-to-face meetings also are needed.
- ✧ The question of funding for the RSIT was raised, but no one knew of any definite information on whether funding would be available.
- ✧ Walt Galloway stated that an important first step for the RSIT would be to agree on its scope. Developing a vision and purpose is among the first tasks of any group. He suggested that the

group start its work by creating a formal written agreement on what the RSIT plans to accomplish.

- ✧ Participants suggested that next steps could include developing a short list of tangible initiatives and deliverables, clarifying the purpose and goal of the RSIT, and examining information from the RSW and other sources to identify priorities. A 1-page research plan would be a valuable deliverable, as would the previously mentioned proposal/white paper aimed at middle and upper management.
- ✧ Ron Landy suggested that a good next step for the RSIT would be to flesh out the matrix that had been displayed earlier in the meeting. The group of people who had volunteered to participate in the RSIT could be tasked with this assignment. Several participants agreed with this proposal. Concerns were raised, however, that the matrix would not indicate which research needs were higher priority than others.

A list of the participants who volunteered to be part of the RSIT follows:

Ralph Abele, Region 1
Charles App, Region 3
Michael Borst, ORD
Lambro Bourodimos, Region 2
Andy Dinsmore, Region 3
Robert Hillger, Region 1
Stu Kerner (until 2/1/10), Region 3
Maureen Krudner, Region 2
Ron Landy, ORD
Audrey Levine, ORD
Dale Manty, ORD
Kevin Maurer, Region 3
Marie O'Shea, Region 2
Steve Silva, Region 1
Joe Williams, ORD

A representative from OW (Rachel Herbert, Abby Hall, and Mary Reilly were suggested as possibilities)

Before adjourning, the group agreed on the following initial action items:

- ✧ Kevin Maurer, Stu Kerner, and Ron Landy will set up an initial conference call, in approximately 2 weeks, for the people who volunteered for the RSIT.
- ✧ Ron Landy and Audrey Levine will follow up with their contacts at OW in an effort to find someone from OW to serve on the RSIT.

Participant List

Ralph Abele

Instream Flow Coordinator
U.S. Environmental Protection Agency, Region 1
One Congress Street
Boston, MA 02114
Phone: 617-918-1629
E-mail: abele.ralph@epa.gov

Diana Abramshe

Project Manager
Stormwater Programs, West-of-Hudson
New York City Department of Environmental
Protection
71 Smith Street
Kingston, NY 12401
Phone: 845-340-7229
E-mail: dabramshe@dep.nyc.gov

Charles App

Environmental Engineer
Environmental Assessment & Innovation
Division
U.S. Environmental Protection Agency, Region 3
Room 3EA00
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-2757
E-mail: app.charles@epa.gov

David Armstrong

Hydrologist
Department of Interior
U.S. Geological Survey
Massachusetts – Rhode Island Water Science
10 Bearfoot Road
Northborough, MA 01532
Phone: 508-490-5060
E-mail: darmstro@usgs.gov

Matthew Baker

Assistant Professor
Geography & Environmental Systems
University of Maryland, Baltimore County
1000 Hilltop Circle
Baltimore, MD 21205
Phone: 410-455-3759
E-mail: mbaker@umbc.edu

Chris Bellucci

Environmental Analyst 3
Connecticut Department of Environmental
Protection
79 Elm Street
Hartford, CT 06016
Phone: 860-424-3735
E-mail: christopher.bellucci@ct.gov

Petronella Best

National Risk Management Research Laboratory
Mail Stop 235
26 West Martin Luther King Drive
Cincinnati, OH 45268
Phone: 513-487-2872
E-mail: elly.best@gmail.com

Sandy Blick

Division of Water Quality
Bureau of Nonpoint Pollution Control
New Jersey Department of Environmental
Protection
P.O. Box 029
401 East State Street
Trenton, NJ 08625
Phone: 609-633-7021
E-mail: sandra.blick@dep.state.nj.us

Michael Borst

Chemical Engineer
U.S. Environmental Protection Agency, Region 2
Mail Stop 104
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6631
E-mail: borst.mike@epa.gov

Lambro Bourodimos

Environmental Engineer
Monitoring Operations Sections
Monitoring and Assessment Branch
Division of Environmental Science and Assessment
U.S. Environmental Protection Agency, Region 2
Mail Stop 220
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6704
E-mail: bourodimos.lampros@epa.gov

Gerald Bright, Jr.

Aquatic Biologist
Office of Watersheds
Philadelphia Water Department Aramark Tower
1101 Market Street
Philadelphia, PA 19107
Phone: 215-685-4953
E-mail: gerald.bright@phila.gov

Ryan Burrows

Research Participant
Oak Ridge Institute for Science and Education
National Risk Management Research Laboratory
Water Supply and Water Resources Research
U.S. Environmental Protection Agency
Mail Stop 689
26 West Martin Luther King Drive
Cincinnati, OH 45268
Phone: 513-569-7243
E-mail: burrows.ryan@epa.gov

Jerry Ciotola

Environmental Engineer
Water Compliance Branch
U.S. Environmental Protection Agency, Region 2
290 Broadway
New York, NY 10007
Phone: 212-637-4223
E-mail: ciotola.jerry@epa.gov

Maria Clark

Environmental Scientist
U.S. Environmental Protection Agency
290 Broadway
New York, NY 10007
Phone: 212-637-3789
E-mail: clark.maria@epa.gov

Shirley Clark

Associate Professor
Environmental Engineering
Penn State, Harrisburg
Room TL-105
777 West Harrisburg Pike
Middletown, PA 17057
Phone: 717-948-6127
E-mail: seclark@psu.edu

Dinorah Dalmasy

Civil Engineer
Senior Regulatory and Compliance Engineer
Total Maximum Daily Load Program
Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230
Phone: 410-537-3699
E-mail: ddalmasy@mde.state.md.us

Naomi Detenbeck

Ecologist
Atlantic Ecology Division
Office of Research and Development
U.S. Environmental Protection Agency
27 Tarzwell Drive
Narragansett, RI 02882
Phone: 401-782-3162
E-mail: detenbeck.naomi@epa.gov

Andy Dinsmore

Stormwater Team Leader
Water Protection Division
U.S. Environmental Protection Agency, Region 3
Suite 3WP42
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-2788
E-mail: dinsmore.andrew@epa.gov

Elizabeth Dragon

Senior Environmental Engineer
New Jersey Department of Environmental
Protection
P.O. Box 029
401 East State Street
Trenton, NJ 08625
Phone: 609-633-7028
E-mail: elizabeth.dragon@dep.state.nj.us

Angus Eaton

New York State Department of Environmental
Conservation
625 Broadway
Albany, NY 12233
Phone: 518-402-8123
E-mail: akeaton@gw.dec.state.ny.us

Raed El-Farhan

Vice President
The Louis Berger Group, Inc.
2445 M Street, NW
Washington, DC 20037
Phone: 202-331-7775
E-mail: relfarhan@louisberger.com

Andy Erickson

Research Fellow
St. Falls Anthony Laboratory
University of Minnesota
2 Third Avenue, SE
Minneapolis, MN 55414
Phone: 612-624-4629
E-mail: eric0706@umn.edu

Melissa Evers
Environmental Specialist
Division of Environmental Assessment
Maine Department of Environmental Protection
28 Tyson Drive
Augusta, ME 04330
Phone: 207-215-3879
E-mail: melissa.evers@maine.gov

Lisa Evrard
Water Resources Program
Rutgers University
14 College Farm Road
New Brunswick, NJ 08901
Phone: 732-932-9800
E-mail: evrard@rci.rutgers.edu

Sandra Fancieullo
U.S. Environmental Protection Agency, Region 1
Suite 1100
1 Congress Street
Boston, MA 02114
Phone: 617-918-1566
E-mail: fancieullo.sandra@epa.gov

Robert Ferri
Geologist
Water Compliance Branch
U.S. Environmental Protection Agency, Region 2
290 Broadway
New York, NY 10007
Phone: 212-637-4227
E-mail: ferri.robert@epa.gov

Rich Field
Leader, Urban Wet-Weather Flow Research Program
National Risk Management Laboratory
U.S. Environmental Protection Agency
Mail Stop 104
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6674
E-mail: field.richard@epa.gov

Kathleen Foley
U.S. Environmental Protection Agency
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 212-637-3574
E-mail: savino.kathleen@epa.gov

Ed Frankel
Section Chief
New Jersey Department of Environmental
Protection
401 East State Street
Trenton, NJ 08625
Phone: 609-633-7021
E-mail: Ed.Frankel@dep.state.nj.us

Mary Freeman
Research Ecologist
University of Georgia River Basin Center
U.S. Geological Survey
Room 101
110 Riverbend Road
Athens, GA 30602
Phone: 706-583-0978
E-mail: mcfreeman@usgs.gov

Bruce Friedman
Supervisor
New Jersey Department of Environmental
Protection
401 East State Street
Trenton, NJ 08625
Phone: 609-633-7021
E-mail: bruce.friedman@dep.state.nj.us

Laura Gabanski
Biologist
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-566-1179
E-mail: gabanski.laura@epa.gov

Mary Galasso
Supervisor, Stormwater Program, EOH
New York City Department of Environmental
Protection
465 Columbus Avenue
Valhalla, NY 10595
Phone: 914-773-4440
E-mail: mgalasso@dep.nyc.gov

Walt Galloway
Environmental Scientist
Atlantic Ecology Division
Office of Research and Development
U.S. Environmental Protection Agency
27 Tarzwell Drive
Narragansett, RI 02817
Phone: 401-782-3096
E-mail: galloway.walt@epa.gov

Luz Garcia
Scientist
U.S. Environmental Protection Agency
P.O. Box 1073
Edison, NJ 08818
Phone: 732-321-6750
E-mail: garcia.luz@epa.gov

Jini Gilchrist
U.S. Environmental Protection Agency, Region 2
Raritan Depot
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6754
E-mail: gilchrist.sivajini@epa.gov

Ariane Giudicelli
Senior Environmental Specialist
New Jersey Department of Environmental
Protection
401 East State Street
Trenton, NJ 08625
Phone: 609-633-1441
E-mail: ariane.giudicelli@dep.state.nj.us

Sandy Goodrow
Water Program Associate
Water Resources Program
Rutgers University
14 College Farm Road
New Brunswick, NJ 08901
Phone: 732-932-9800
E-mail: sgoodrow@envsci.rutgers.edu

Allison Graham
U.S. Environmental Protection Agency, Region 3
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-2373
E-mail: graham.allison@epa.gov

Jeffrey Gratz
Chief, Clean Water Regulatory Branch
U.S. Environmental Protection Agency, Region 2
290 Broadway
New York, NY 10007
Phone: 212-637-3873
E-mail: gratz.jeff@epa.gov

Helen Grebe
U.S. Environmental Protection Agency, Region 2
Raritan Depot
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6797
E-mail: grebe.helen@epa.gov

Dana Gumb
Director
Staten Island Bluebelt
New York City Department of Environmental
Protection
59-17 Junction Boulevard
Flushing, NY 11373
Phone: 718-595-7459
E-mail: dgumb@dep.nyc.gov

Lisa Hair
U.S. Environmental Protection Agency
Room 4503T
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-566-1043
E-mail: hair.lisa@epa.gov

Abby Hall
U.S. Environmental Protection Agency
Room 1807T
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-566-2086
E-mail: hall.abby@epa.gov

Fred Hauchman
Director
Office of Science Policy
Office of Research and Development
U.S. Environmental Protection Agency
Room 8104R
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-564-6705
E-mail: hauchman.fred@epa.gov

Carolyn Hayek
U.S. Environmental Protection Agency, Region 1
Suite 1100
1 Congress Street
Boston, MA 02114
Phone: 617-918-1596
E-mail: hayek.carolyn@epa.gov

Rachel Herbert
Physical Scientist
Office of Wastewater Management/Water
Permits Division
U.S. Environmental Protection Agency
Room 4203M
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-564-2649
E-mail: herbert.rachel@epa.gov

Robert Hillger

Senior Science Advisor
U.S. Environmental Protection Agency, Region 1
11 Technology Drive
Chelmsford, MA 01863
Phone: 617-918-8660
E-mail: hillger.robert@epa.gov

Jessica Hing

Environmental Scientist
U.S. Environmental Protection Agency
1 Congress Street
Boston, MA 02114
Phone: 617-918-1560
E-mail: hing.jessica@epa.gov

James Houle

University of New Hampshire
214 Gregg Hall
35 Colovos Road
Durham, NH 03824
Phone: 603-767-7091
E-mail: james.houle@unh.edu

Patricia Ingelido

New Jersey Department of Environmental
Protection
401 East State Street
Trenton, NJ 08625
Phone: 609-633-1441
E-mail: patricia.ingelido@dep.state.nj.us

Shohreh Karimipour

Environmental Engineer
New York State Department of Environmental
Conservation
625 Broadway
Albany, NY 12233
Phone: 518-402-8102
E-mail: sxkarimi@gw.dec.state.ny.us

Jonathan Kennen

Biologist
U.S. Geological Survey
Suite 206
810 Bear Tavern Road
West Trenton, NJ 08628
Phone: 609-771-3948
E-mail: jgkennan@usgs.gov

Stu Kerzner

Science Liaison
Environmental Assessment & Innovation Division
U.S. Environmental Protection Agency, Region 3
3EA00
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-5709
E-mail: kerzner.stuart@epa.gov

Matthew Klewin

Senior Environmental Specialist
New Jersey Department of Environmental
Protection
State of New Jersey
P.O. Box 029
401 East State Street
Trenton, NJ 08625
Phone: 609-292-0407
E-mail: matt.klewin@dep.state.nj.us

Mike Kline

Rivers Program Manager
Department of Environmental Conservation
River Management Program
10 North Building
103 South Main Street
Waterbury, VT 05671
Phone: 802-241-3774
E-mail: mike.kline@state.vt.us

Kenneth Klipstein

Director, Watershed Protection Unit
New Jersey Water Supply Authority
74 East Main Street
Somerville, NJ 08876
Phone: 908-685-0315, ext. 223
E-mail: kklipstein@rارانbasin.org

Maureen Krudner

U.S. Environmental Protection Agency, Region 2
24th Floor
290 Broadway
New York, NY 10309
Phone: 212-637-3874
E-mail: krudner.maureen@epa.gov

Jim Kurtenbach

U.S. Environmental Protection Agency, Region 2
Raritan Depot
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6695
E-mail: kurtenbach.james@epa.gov

Pete LaFlamme

Water Quality Division Director
Vermont Department of Environmental
Conservation
103 South Main Street
Waterbury, VT 05671
Phone: 802-241-3765
E-mail: pete.laflamme@state.vt.us

Dennis Lai

Environmental Engineer
Urban Watershed Management Branch
Office of Research and Development
U.S. Environmental Protection Agency
Mail Stop 104
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6632
E-mail: lai.dennis@epa.gov

Ronald Landy

Acting Director of the Regional Science Program
Office of Research and Development
U.S. Environmental Protection Agency
701 Mapes Road
Fort Meade, MD 21797
Phone: 410-305-2757
E-mail: landy.ronald@epa.gov

Murray Lantner

U.S. Environmental Protection Agency, Region 2
20th Floor
290 Broadway
New York, NY 10007
Phone: 212-637-3976
E-mail: lantner.murray@epa.gov

Audrey Levine

U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-564-1070
E-mail: levine.audrey@epa.gov

Louisa Lubiak

Senior Environmental Specialist
Bureau of Nonpoint Pollution Control
New Jersey Department of Environmental
Protection
P.O. Box 029
401 East State Street
Trenton, NJ 08625
Phone: 609-633-7021
E-mail: louisa.lubiak@dep.state.nj.us

Bill Lucas

Principal
Integrated Land Management, Inc.
3 Lucas Lane
Malvern, PA 19355
Phone: 610-644-0606
E-mail: wlucas@integratedland.com

Kevin Magerr

U.S. Environmental Protection Agency, Region 3
Room 3EA30
1650 Arch Street
Wilmington, DE 19810
Phone: 215-814-5724
E-mail: magerr.kevin@epa.gov

Katherine Mann

Physical Scientist
Division of Enforcement and Compliance Assistance
U.S. Environmental Protection Agency, Region 2
20th Floor
290 Broadway
New York, NY 10007
Phone: 212-637-4226
E-mail: mann.katherine@epa.gov

Dale Manty

National Center for Environmental Research
Office of Research & Development
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-343-9738
E-mail: manty.dale@epa.gov

Hank Mazzucca

Chief, Compliance Section
Defense Commissary Agency
U.S. Environmental Protection Agency
Room 2033
290 Broadway
New York, NY 10007
Phone: 212-637-4229
E-mail: mazzucca.henry@epa.gov

Kimberly McEathron

Water Compliance Branch
Division of Enforcement and Compliance Assistance
U.S. Environmental Protection Agency, Region 2
20th Floor
290 Broadway
New York, NY 10007
Phone: 212-637-4228
E-mail: mceathron.kimberly@epa.gov

Art McGarity

Professor of Engineering
Engineering Department
Swarthmore College
Hicks Hall
500 College Avenue
Swarthmore, PA 19081
Phone: 610-328-6676
E-mail: amcgarity@swarthmore.edu

David McGuigan

U.S. Environmental Protection Agency, Region 3
Room 3WP40
1650 Arch Street
Wilmington, DE 19103
Phone: 215-814-2158
E-mail: mcguigan.david@epa.gov

Brian Mitchell

Principal Environment Engineer
Interstate Environmental Commission
311 West 43rd Street
New York, NY 10036
Phone: 212-582-0380
E-mail: bmitchell@iec-nynjct.org

Jeff Moeller

Senior Program Director
Water Environment Research Foundation
Suite 300
635 Slaters Lane
Alexandria, VA 22314
Phone: 703-684-2461
E-mail: jmoeller@werf.org

Yusuf Mohamoud

Research Hydrologist
Ecosystems Research Division
U.S. Environmental Protection Agency
960 College Station Road
Athens, GA 30605
Phone: 770-495-0026
E-mail: mohamoud.yusuf@epa.gov

Heidi Moltz

Senior Water Resources Scientist
Interstate Commission on the Potomac River
Basin
Room PE-08
51 Monroe Street
Rockville, MD 20850
Phone: 301-274-8116
E-mail: hmoltz@icprb.org

Franco Montalto

Assistant Professor
Civil, Architectural & Environmental Engineering
Drexel University
Room 273-F
Curtis Hall
3141 Chestnut Street
Philadelphia, PA 19104
Phone: 215-895-1385
E-mail: fmontalto@coe.drexel.edu

Christopher Moore

Oak Ridge Institute for Science and Education
Fellow
Office of Wastewater Management
U.S. Environmental Protection Agency
Room 4203M
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-564-7299
E-mail: moore.christopher@epa.gov

Caitlyn Nichols

Environmental Specialist
Interstate Environmental Commission
311 West 43rd Street
New York, NY 10036
Phone: 212-582-0380
E-mail: cnichols@iec-nynjct.org

Laura Nicholson

Research Scientist
New Jersey Geological Survey
New Jersey Department of Environmental
Protection
P.O. Box 427
29 Arctic Parkway
Trenton, NJ 08427
Phone: 609-984-6587
E-mail: laura.nicholson@dep.state.nj.us

Jennifer Noblejas

Principal Environmental Specialist
New Jersey Department of Environmental
Protection
401 East State Street
Trenton, NJ 08625
Phone: 609-633-0733
E-mail: jennifer.noblejas@dep.state.nj.us

Doug Norton

Senior Environmental Scientist
Office of Water
U.S. Environmental Protection Agency
Room 4503T
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-566-1221
E-mail: norton.douglas@epa.gov

Robert Nyman

Director
Harbor Estuary Program Office
U.S. Environmental Protection Agency, Region 2
24th Floor
290 Broadway
New York, NY 10007
Phone: 212-637-3809
E-mail: nyman.robert@epa.gov

Thomas O'Connor

Environmental Engineer
Office of Research and Development
U.S. Environmental Protection Agency
Mail Stop 104
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6723
E-mail: oconnor.thomas@epa.gov

Leah O'Neill

U.S. Environmental Protection Agency, Region 1
1 Congress Street
Boston, MA 02114
Phone: 617-918-1633
E-mail: oneill.leah@epa.gov

Marie O'Shea

U.S. Environmental Protection Agency, Region 2
290 Broadway
New York, NY 10007
Phone: 212-637-3585
E-mail: oshea.marie@epa.gov

Kwabena Osei

Manager
Research and Development
Product Development
Hydro International
94 Hutchins Drive
Portland, ME 04102
Phone: 207-321-3745
E-mail: kosei@hil-tech.com

Elizabeth Ottinger

Environmental Engineer
U.S. Environmental Protection Agency, Region 3
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-5783
E-mail: ottinger.elizabeth@epa.gov

Helen Pang

Research Scientist
Division of Watershed Management
New Jersey Department of Environmental
Protection
P.O. Box 418
401 East State Street
Trenton, NJ 08625
Phone: 609-292-7760
E-mail: helen.pang@dep.state.nj.us

Kunal Patel

Senior Environmental Engineer
Division of Water Quality
New Jersey Department of Environmental
Protection
401 East State Street
Trenton, NJ 08625
Phone: 609-777-0121
E-mail: kunal.patel@dep.state.nj.us

Ben Pearson

Water Resources Program
Rutgers University
14 College Farm Road
New Brunswick, NJ 08901
Phone: 732-932-9800
E-mail: bpearson@envsci.rutgers.edu

Eric Perkins

Water Quality Coordinator
U.S. Environmental Protection Agency, Region 1
Suite 1100
1 Congress Street
Boston, MA 02114
Phone: 617-918-1602
E-mail: perkins.eric@epa.gov

Zeyuan Qiu

Associate Professor
Department of Chemistry and Environmental Science
New Jersey Institute of Technology
323 Dr. Martin Luther King Boulevard
Newark, NJ 07102
Phone: 973-596-5357
E-mail: zeyuan.qiu@njit.edu

Asim Ray

Research Scientist
U.S. Environmental Protection Agency, Region 2
Raritan Depot
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-906-6822
E-mail: ray.asim@epa.gov

Todd Richards

Massachusetts Division of Fisheries and Wildlife
1 Rabbit Hill Road
Westborough, MA 01851
Phone: 508-792-7270, ext. 138
E-mail: todd.richards@state.ma.us

Donna Ringel

Quality Assurance Officer
U.S. Environmental Protection Agency, Region 2
Mail Stop 220
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-4383
E-mail: ringel.donna@epa.gov

Bruce Rodan

Office of Science Policy
Office of Research and Development
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 202-564-6780
E-mail: rodan.bruce@epa.gov

Robert Roseen

University of New Hampshire
242 Gregg Hall
35 Colovos Road
Durham, NH 03824
Phone: 603-862-4024
E-mail: robert.roseen@unh.edu

Amy Rowe

Office of Research and Development
U.S. Environmental Protection Agency
Mail Stop 104
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-906-6823
E-mail: rowe.amy@epa.gov

Allison Roy

Assistant Professor
Department of Biology
Kutztown University
P.O. Box 730
Kutztown, PA 19530
Phone: 610-683-4318
E-mail: roy@kutztown.edu

Laura Rozumalski

Office of Watersheds
Philadelphia Water Department
1101 Market Street
Philadelphia, PA 19107
Phone: 215-685-6234
E-mail: laura.rozumalski@phila.gov

Tham Saravanapavan

Tetra Tech, Inc.
Suite 340
10306 Eaton Place
Fairfax, VA 22030
Phone: 703-385-6000
E-mail: tham.saravanapavan@tetrattech.com

Dibs Sarkar

Program Director
Environmental Management
Montclair State University
Room ML 116
1 Normal Avenue
Montclair, NJ 07043
Phone: 973-655-7273
E-mail: sarkard@mail.montclair.edu

Nancy Schlotter

U.S. Environmental Protection Agency
290 Broadway
New York, NY 10007
Phone: 212-637-3947
E-mail: schlotter.nancy@epa.gov

Kate Schofield

Ecologist
Office of Research and Development
U.S. Environmental Protection Agency
Room MC 8623P
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Phone: 703-347-8533
E-mail: schofield.kate@epa.gov

Thomas Schueler

Chesapeake Stormwater Network
117 Ingleside Avenue
Baltimore, MD 21228
Phone: 410-455-9441
E-mail: watershedguy@hotmail.com

Stu Schwartz

Senior Research Scientist
Center for Urban Environmental Research and
Education
University of Maryland, Baltimore County
Room 102
Technology Research Center
1000 Hilltop Circle
Baltimore, MD 21250
Phone: 410-455-2748
E-mail: stu_schwartz@umbc.edu

Ari Selvakumar

Environmental Engineer
Office of Research and Development
U.S. Environmental Protection Agency
Mail Stop 104
2890 Woodbridge Avenue
Edison, NJ 08827
Phone: 732-906-6990
E-mail: selvakumar.ariamalar@epa.gov

Dianne Shatin

Bureau of Environmental Analysis and Restoration
New Jersey Department of Environmental Protection
401 East State Street
Trenton, NJ 08625
Phone: 609-777-1405
E-mail: dianne.shatin@dep.state.nj.us

Sheri Shifren

New Jersey Department of Environmental
Protection
401 East State Street
Trenton, NJ 08054
Phone: 609-633-7021
E-mail: sheri.shifren@dep.state.nj.us

Leslie Shoemaker

Vice President
Strategic Initiatives
Tetra Tech, Inc.
10306 Eaton Place
Fairfax, VA 22030
Phone: 703-385-6000
E-mail: leslie.shoemaker@tetrattech.com

Steve Silva

Chief
Water Quality Branch
U.S. Environmental Protection Agency, Region 1
1 Congress Street
Boston, MA 02114
Phone: 617-918-1561
E-mail: silva.stephen@epa.gov

Ruth Sittler

Stormwater Planning and Management
Bureau of Watershed Management
Pennsylvania Department of Environmental
Protection
P.O. Box 8775
400 Market Street
Harrisburg, PA 17057
Phone: 717-772-5632
E-mail: rusittler@state.pa.us

Tom Southard

Manager
Neshanic Project
South Branch Watershed Association
41 Lilac Drive
Flemington, NJ 08822
Phone: 908-782-0422, ext. 15
E-mail: tomsouthard@sbwa.org

Barbara Spinweber

Coordinator
Barnegat Bay Program
U.S. Environmental Protection Agency, Region 2
290 Broadway
New York, NY 10007
Phone: 212-637-3812
E-mail: spinweber.barbara@epa.gov

Betsy Stagg

Environmental Management
College of Science and Mathematics
Montclair State University
1 Normal Avenue
Montclair, NJ 07043
Phone: 973-655-3456
E-mail: bstagg181@aol.com

Emilie Stander

Environmental Scientist
Urban Watershed Management Branch
U.S. Environmental Protection Agency
Mail Stop 104
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-906-6898
E-mail: stander.emilie@epa.gov

Stan Stephansen

Environmental Scientist
Clean Water Regulatory Branch
U.S. Environmental Protection Agency, Region 2
24th Floor
290 Broadway
New York, NY 10007
Phone: 212-637-3776
E-mail: stephansen.stanley@epa.gov

Mary Stinson

Physical Scientist
Urban Watershed Management
Water Supply and Water Resources Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Mail Stop 104
2890 Woodbridge Avenue
Edison, NJ 08837
Phone: 732-321-6683
E-mail: stinson.mary@epa.gov

Hale Thurston

U.S. Environmental Protection Agency
Suite 443
26 West Martin Luther King Drive
Cincinnati, OH 45268
Phone: 513-569-7627
E-mail: thurston.hale@epa.gov

Rob Traver

Professor
Civil and Environmental Engineering Department
Villanova University
800 Lancaster Avenue
Villanova, PA 19085
Phone: 610-519-7899
E-mail: robert.traver@villanova.edu

Angel Valdez

Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230
Phone: 410-537-3902
E-mail: gwallace@mde.state.md.us

Steve Venezia

Storm Water Coordinator
U.S. Environmental Protection Agency, Region 2
290 Broadway
New York, NY 10007
Phone: 212-637-3856
E-mail: venezia.stephen@epa.gov

Mark Voorhees

Environmental Engineer
U.S. Environmental Protection Agency
Suite 1100
1 Congress Street
Boston, MA 02114
Phone: 617-918-1537
E-mail: voorhees.mark@epa.gov

Lizhong Wang

Postdoctoral Fellow
New Jersey Institute of Technology
University Heights
Newark, NJ 07102
Phone: 973-596-3454
E-mail: lizhong.wang@njit.edu

Kordell Wilen

Vice President – Engineering
American Engineering and Surveying, Inc.
224 East Main Street
Elkton, MD 21921
Phone: 410-398-5000
E-mail: kordell.wilen@americanengineering.net

Charles Zafonte

Multimedia Enforcement Coordinator
U.S. Environmental Protection Agency
290 Broadway
New York, NY 10007
Phone: 212-637-3515
E-mail: zafonte.charles@epa.gov

**EPA SUPPORT SERVICES CONTRACTOR
PERSONNEL****Kelly A. Doran**

Conference Planner
BLH Technologies, Inc.
Suite 615
1803 Research Boulevard
Rockville, MD 20850
Phone: 240-399-8745
E-mail: kdoran@blhtech.com

Kathleen Meister

Notetaker/Writer
The Scientific Consulting Group, Inc.
Suite 210
656 Quince Orchard Road
Gaithersburg, MD 20878
Phone: 301-670-4990
E-mail: kmeister@scgcorp.com